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ANNOUNCEMENT.

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HUGH M. SMITH,
Secretary-General.

CONTENTS.

PART 1.

	Page.
ORGANIZATION AND SESSIONAL BUSINESS	1
INTERNATIONAL REGULATIONS OF THE FISHERIES ON THE HIGH SEAS. By O. T. Olsen. With discussion	77
INTERNATIONAL REGULATIONS OF THE FISHERIES ON THE HIGH SEAS. By Charles Edward Fryer.	91
INTERNATIONAL REGULATIONS OF THE FISHERIES ON THE HIGH SEAS. By Charles Hugh Stevenson. With discussion	103
WORK OF THE INTERNATIONAL FISHERIES COMMISSION OF GREAT BRITAIN AND THE UNITED STATES. By David Starr Jordan	181
SOME REASONS FOR FAILURE OF FISH PROTECTIVE LEGISLATION AND SOME SUGGESTED REMEDIES. By Oregon Milton Dennis	187
NATIONAL ASPECTS OF ANGLING AND THE PROTECTION OF GAME FISHES. By H. Wheeler Perce.	193
SPORT FISHING IN CALIFORNIA AND FLORIDA. By Charles F. Holder	199
LOBSTERS AND THE LOBSTER PROBLEM IN MASSACHUSETTS. By George W. Field. With discussion	209
A METHOD OF LOBSTER CULTURE. By A. D. Mead	219
SEA MUSSELS AND DOGFISH AS FOOD. By Irving A. Field. With discussion	241
THE WHOLESOMENESS OF OYSTERS AS FOOD. By Henry C. Rowe	259
EFFECTS OF MENHADEN FISHING UPON THE SUPPLY OF MENHADEN AND OF THE FISHES THAT PREY UPON THEM. By Walter E. Hathaway. With discussion	269
EFFECTS OF THE MENHADEN AND MACKEREL FISHERIES UPON THE FISH SUPPLY. By W. C. Kendall	279
AN IMPROVED AND PRACTICAL METHOD OF PACKING FISH FOR TRANSPORTATION. By A. Sölling.	295
A PROCESS FOR PRESERVING THE PEARL-OYSTER FISHERIES AND FOR INCREASING THE VALUE OF THE YIELD OF PEARLS. By John I. Solomon	303
FUR SEALS AND THE SEAL FISHERIES. By Charles H. Townsend	315
ECONOMIC CONDITIONS OF THE FISHERIES IN ITALY. By Guido Rossati	323
THE FISHERIES AND THE GUANO INDUSTRY OF PERU. By Robert E. Coker	333
THE FISHERIES OF CHINA. By Wei-Ching W. Yen	367
THE FISHERIES OF JAPAN CONSIDERED FROM A GEOGRAPHICAL STANDPOINT. By T. Kitahara	375
GOLDFISH AND THEIR CULTURE IN JAPAN. By Shinnosuke Matsubara	381
COMMERCIAL SPONGES AND THE SPONGE FISHERIES. By H. F. Moore	399
THE ABUSE OF THE SCAPHANDER IN THE SPONGE FISHERIES. By Ch. Flégel	513
A PRACTICAL METHOD OF SPONGE CULTURE. By H. F. Moore	545
SPONGE CULTURE. By Jules Cotte	587
EXPERIMENTS IN THE ARTIFICIAL PROPAGATION OF FRESH-WATER MUSSELS. By George Lefevre and W. C. Curtis	615
A PLAN FOR PROMOTING THE WHITEFISH PRODUCTION OF THE GREAT LAKES. By S. W. Downing.	627
A PLAN FOR PROMOTING THE WHITEFISH PRODUCTION OF THE GREAT LAKES. By Frank N. Clark.	635
A PLAN FOR PROMOTING THE WHITEFISH PRODUCTION OF THE GREAT LAKES. By Paul Reighard.	643
Discussion of whitefish question	655

PART 2.

FISH-CULTURAL PRACTICES IN THE BUREAU OF FISHERIES. By John W. Titcomb	697
A NEW PRINCIPLE OF AQUICULTURE AND TRANSPORTATION OF LIVE FISHES. By A. D. Mead.	759
A METHOD OF CULTIVATING RAINBOW TROUT AND OTHER SALMONIDÆ. By Charles L. Paige	781
POSSIBLE EXPANSION OF SHAD-HATCHERY WORK. By S. G. Worth	789
THE COMPARATIVE VALUE OF FOODS FOR RAINBOW TROUT AND OTHER SALMONOIDS. By Charles L. Paige	795
APPARATUS AND METHODS EMPLOYED AT THE MARINE FISH HATCHERY AT FLÖDEVIG, NORWAY. By G. M. Dannevig	799
THE UTILITY OF SEA-FISH HATCHING. By G. M. Dannevig	811

Page.

Propagation and protection of the Rhine salmon. By P. P. C. Hoek 817
Fishes in their relation to the mosquito problem. By William P. Seal 831
Foods for young salmonoid fishes. By Charles G. Atkins 839
Fresh-water shrimp, a natural fish food. By S. G. Worth 853
The cultivation of the turbot. By R. Anthony 859
The treatment of fish-cultural waters for the removal of algæ. By M. C. Marsh and R. K. Robinson 871
Notes on the dissolved content of water in its effect upon fishes. By M. C. Marsh ... 891
Causes of disease in young salmonoids. By Eugene Vincent 907
Radical prevention of Costia necatrix in salmonoid fry. By Johann Franke 917
Treatment of fungus on fishes in captivity. By L. B. Spencer 929
Methods of combating fungus on fishes in captivity. By Charles F. Holder 933
A new method of combating fungus on fishes in captivity. By Paul Zirzow 937
Eighteen months' experience with a disease of brook trout. By Albert Rosenberg 941
American fishes in Italy. By Giuseppe Besana 947
Acclimatization of American fishes in Argentina. By E. A. Tulian 955
The introduction of American fishes into New Zealand. By L. F. Ayson. With discussion 967
Naturalization of American fishes in Austrian waters. By Franz von Pirko 977
Causes of degeneration of American trouts in Austria. By Johann Franke 983
New and improved devices for fish culturists. By Alfred E. Fuller 991
A device for counting young fish. By Robert K. Robinson 1001
A method of transporting live fishes. By Charles F. Holder 1005
A method of measuring fish eggs. By H. von Bayer 1009
An improvement in hatching and rearing boxes; with notes on continuous feeding of the fry of Salmonidæ. By G. E. Simms 1015
Devices for use in fish hatcheries and aquaria. By Eugene Vincent 1025
New methods of transporting eggs and fish. By W S. Kincaid 1037
Fishways. By H. von Bayer 1041
A plea for observation of the habits of fishes and against undue generalization. By Theodore Gill. With discussion 1059
The habits and life history of the toadfish (Opsanus tau). By E. W. Gudger 1071
Methods of studying the habits of fishes and recording their life histories; with an account of the breeding habits of the horned dace. By Jacob Reighard 1111
A method of observing the habits and recording the life histories of fishes. By Charles F. Holder 1137
Effects of changes in the density of water upon the blood of fishes. By George G. Scott. 1143
Internal parasites of the Sebago salmon. By Henry B. Ward 1151
Notes on the flesh parasites of marine food fishes. By Edwin Linton 1195
Structure and functions of the ear of the squeteague. By G. H. Parker 1211
An intensive study of the fauna and flora of a restricted area of sea bottom. By Francis B. Sumner 1225
Development of sponges from tissue cells outside the body of the parent. By H. V. Wilson 1265
Gases dissolved in the waters of Wisconsin lakes. By E. A. Birge. With discussion .. 1273
Volumetric studies of the food and feeding of oysters. By H. F. Moore 1295
A plan for an educational exhibit of fishes. By Charles F. Holder 1309
A plan for an educational exhibit of fishes. By Roy W. Miner 1315
Outline for an educational exhibit of fishes. By F. A. Lucas 1341
A method of preparing fish for museum and exhibition purposes. By Dwight Franklin. 1353
New methods of preparing fishes for museum exhibit. By J. D. Figgins 1357
The United States Bureau of Fisheries: Its establishment, functions, organization, resources, operations, and achievements. By Hugh M. Smith 1365
General index .... I–XII

ILLUSTRATIONS.

PLATES—PART I.

SPORT FISHING IN CALIFORNIA AND FLORIDA: Facing page.

Plate I. (1 and 2) Angling for black sea bass, Santa Catalina Island, California... 208

II. (3) Weighing a big sea bass. (4) The record bonito, Tuna Club, 1908, rod and reel.......... 208

III. (5) Angling for tuna, Santa Catalina. (6) Leaping tuna caught with rod and reel at Santa Catalina.......... 208

IV. (7) A day's sport at Santa Catalina Island. (8) The yellow-tail anglers of Avalon Bay, California.......... 208

V. (9) The record sunfish, Santa Catalina. (10) A salmon (rod and reel) catch, Del Monte, California.......... 208

VI. (11) Swordfish, yellow-fin tuna and yellow-tail, caught with rod and reel at Santa Catalina Island. (12) Amberjack, caught at Palm Beach, Florida.......... 208

A METHOD OF LOBSTER CULTURE:

Plate VII. (1) General view of houseboat and floats. (2) Inside of rearing box toward one corner.......... 240

VIII. (3) Floats from outer corner looking forward. (4) One of the outside floats, car raised.......... 240

IX. (5) Transferring fry from one car to another. (6) Feeding the fry...... 240

X. (7) Method of counting fourth-stage lobsters. (8) Improved towing car. 240

XI. (9) Lobster with eggs.......... 240

THE FISHERIES AND THE GUANO INDUSTRY OF PERU:

Plate XII. (1) A characteristic scene on the coast desert. (2) Mouth of the River Rimac near Callao.......... 366

XIII. (3) Gathering oysters from the mangrove trees, Tumbes. (4) Native fisherman in the surf, throwing the ataraya (cast net).......... 366

XIV. (5) A Peruvian fishing with hook and line from a caballito, Pacasmayo. (6) Balsa on Lake Titicaca, made of reeds.......... 366

XV. (7) Drying sharks, guitar-fishes, etc., without the use of salt, Lobos de Tierra. (8) Sacking guano to be shipped by anda-rivel (automatic trolley), Ballestas Islands.......... 366

XVI. (9) A very small portion of a flock of cormorants on the south island of the Chinchas. (10) A small flock of cormorants on the south island of the Ballestas, gannets barely distinguishable on the ledges.......... 366

XVII. (11) Pelicans on their nests, Lobos de Afuera.......... 366

GOLDFISH AND THEIR CULTURE IN JAPAN:

Plate XVIII. Wakin.......... 398

XIX. Ryukin.......... 398

XX. Ranchu.......... 398

XXI. Oranda shishigashira.......... 398

XXII. Demekin.......... 398

XXIII. Deme ranchu.......... 398

XXIV. Watonai.......... 398

XXV. Shukin.......... 398

XXVI. Shubunkin.......... 398

XXVII. Kinranshi.......... 398

COMMERCIAL SPONGES AND THE SPONGE FISHERIES: Facing page.
Plate XXVIII. Specimen of rock from sponge beds off Anclote Key, Florida 403
XXIX. (1) Diving boat, with cured catch. (2) Diving boat hauled out 446
XXX. Rock Island sheepswool sponge 512
XXXI. Same 512
XXXII. Florida Key sheepswool sponge 512
XXXIII. Matecumbe Key sheepswool sponge 512
XXXIV. Nassau sheepswool sponge, Bahama Islands 512
XXXV. Abaco sheepswool sponge, Bahama Islands 512
XXXVI. Cuba sheepswool sponge 512
XXXVII. Florida Key yellow sponge 512
XXXVIII. Same 512
XXXIX. Same 512
XL. Anclote yellow sponge 512
XLI. Same 512
XLII. Bahama yellow sponge 512
XLIII. Same 512
XLIV. Cuba yellow sponge 512
XLV. Florida velvet sponge 512
XLVI. Bahama velvet sponge 512
XLVII. Cuba velvet sponge 512
XLVIII. Anclote grass sponge 512
XLIX. Florida Key grass sponge 512
L. Same 512
LI. Same 512
LII. Bahama grass sponges 512
LIII. Cuba grass sponges 512
LIV. Florida glove sponge 512
LV. Cuba reef sponge 512
LVI. Bahama reef sponges 512
LVII. Cuba hardhead sponges 512
LVIII. Florida wire sponge 512
LIX. Same 512
LX. Turkey cup sponges, Mediterranean Sea 512
LXI. (1) Turkey solid sponge, Mediterranean Sea. (2) Toilet sponge, Mediterranean Sea 512
LXII. Toilet sponge, Mediterranean Sea 512
LXIII. Philippine toilet sponges 512
LXIV. Zimocca sponges, Mediterranean Sea 512
LXV. Honeycomb sponge, Mediterranean Sea 512
LXVI. Elephant-ear sponge, Mediterranean Sea 512
A PRACTICAL METHOD OF SPONGE CULTURE:
Plate LXVII. Sponges growing on cement triangles used in experimental plants of cuttings 547
LXVIII. Cement disks with cuttings mounted, showing spindle and wire attachments 566
LXIX. (1) Sheepswool cutting about size recommended for planting. (2) Sheepswool sponge about 11 months old, grown from cutting 586
LXX. (1) Sheepswool sponge 20 months old, grown from cutting. (2) Yellow sponge 21 months old, grown from cutting 586
LXXI. Sheepswool sponge 31 months old, grown from cutting 586
LXXII. Sheepswool sponge 35 months old, grown from cutting 586
LXXIII. Sheepswool sponge 52 months old, grown from cutting 586

A PRACTICAL METHOD OF SPONGE CULTURE—Continued. Facing page.
Plate LXXIV. Sheepswool sponge 35 months old, grown from cutting 586
LXXV. Sheepswool sponge not over 48 months old, grown from cutting 586
LXXVI. Sheepswool sponge not over 48 months old, grown from cutting 586

PLATES—PART 2.

FISH-CULTURAL PRACTICES IN THE UNITED STATES BUREAU OF FISHERIES:
Plate LXXVII. (1) Brook trout eggs on tray, just beginning to hatch. (2) Brook trout fry in trough, sac stage. (3) Brook trout fry, sac nearly absorbed, about ready to feed 699
LXXVIII. (4) Hatching equipment for shad and other semibuoyant eggs 702
LXXIX. (5 and 6) Taking spawn of whitefish, Detroit River, Michigan 706
LXXX. (7) Interior of hatchery at Put-in Bay, Ohio. (8) Downing jars set up for use 710
LXXXI. (9) Capturing blackspotted trout in small tributary of Grand Mesa Lake, Colorado. (10) Trap for capturing spawning rainbow trout, Lake San Cristobal, Colorado 712
LXXXII. (11) Field hatchery at Grand Mesa Lakes, Colorado. (12) Tray of trout eggs in hatching trough 714
LXXXIII. (13) Series of covered trout-hatching troughs at White Sulphur Springs station, West Virginia. (14) Trout-hatching troughs with Merrill aerating cone 718
LXXXIV. (15) Placing cheese-cloth retainers in pond over nests containing bass fry. (16) Pond drawn down and nest boxes placed for spawning 720
LXXXV. (17) View of fish-culture station at Manchester, Iowa, showing trout and bass ponds. (18) Preparing a shipment of black bass 724
LXXXVI. (19) Main rack across Battle Creek, California, for intercepting spawning salmon. (20) Seining spawning salmon on the McCloud River, California 728
LXXXVII. (21) Spawntaking operations (salmon) at Baird, California. (22) One method of stripping steelhead trout 734
LXXXVIII. (23) Equipment of McDonald automatic tidal boxes for hatching cod. (24) Berried lobsters in course of transfer to hatchery 738
LXXXIX. (25) Box of trout eggs just opened after shipment. (26) Tray of trout eggs with mosquito net and moss in which packed 742
A NEW PRINCIPLE OF AQUICULTURE AND TRANSPORTATION OF LIVE FISHES:
Plate XC. (1) Floating laboratory and rearing plant from port side. (2) General view from outer rear corner 761
XCI. (3) Starboard side, looking aft, inside float. (4) Car with propeller in motion 780
XCII. (5) Rearing car raised and held up by portable windlass. (6) Interior of rearing car, and propeller 780
XCIII. (7) Lifting disconnected propeller out of water. (8) Propeller removed, showing disconnected shaft 780
XCIV. (9) Cleat at end of holding-down plank. (10) Cleats removed, car rising .. 780
XCV. (11) Interior of rearing car. (12) Raising car by means of windlass 780
XCVI. (13) View of interior of a car, showing filter of gravel. (14) Filter car in operation 780
XCVII. (15) Filter car, showing bucket chain in operation. (16) Filter car with canvas lining 780
XCVIII. (17) Detail of device for extension and universal movement. (18) Detail of lower portion of propeller shaft and its socket in floor of car 780

Facing page.

A NEW PRINCIPLE OF AQUICULTURE AND TRANSPORTATION OF LIVE FISHES—Continued.

Plate XCIX. (19) Detail of propeller shaft couplings. (20) Detail of gears on float at junction of transverse and longitudinal shafts 780

C. (21) Detail of device for throwing propeller in and out of gear. (22) Operation of device for throwing propeller out of gear 780

APPARATUS AND METHODS EMPLOYED AT THE MARINE FISH HATCHERY AT FLÖDEVIG, NORWAY:

Plate CI. (1) Egg collector. (2) Eccentric wheel providing circulation of water in hatching boxes 810

CULTIVATION OF THE TURBOT:

Plate CII. (1) Turbot eggs with embryo. (2) Larva with vitellus. (3) Larva with vitellus almost entirely resorbed—beginning of critical period 870

CIII. (4) Larva a few days after end of critical period. (5) Detail of pigmentation of abdomen of above figure. (6) Larva after critical period 870

NEW AND IMPROVED DEVICES FOR FISH CULTURISTS:

Plate CIV. (1) Artificial bass nest. (2) Bass fry retaining screen and trap. (3) Collecting tub, with float 1000

CV. (4) Fish retainer, with float. (5) Fish attendant's outfit—aerator screen, plunger, combined ice pick and scaff net 1000

CVI. (6) Seine for collecting fingerling bass. (7) Shipping case for fish eggs 1000

HABITS AND LIFE HISTORY OF THE TOADFISH, OPSANUS TAU:

Plate CVII. (1) Reproductive organs of the toadfish. (2) Ventral aspect of ripe ovary. 1110

CVIII. (3) One-half of *Pinna* shell nest, showing live eggs in segmentation. (4) Eggs in late segmentation 1110

CIX. (5) Board nest, eggs with late blastoderm and early embryos. (6) Nest showing embryos having marked enlargement at one end 1110

CX. (7) *Pinna* shell nest, showing tadpole-like larvæ. (8) Board nest. Larvæ slightly older than in figure 7 1110

CXI. (9) *Pinna* shell nest, late larval toadfish. (10) Late larval toadfish, showing color markings 1110

CXII. (11) Same nest as figure 10. The young nearly ready to break away. (12) From instantaneous photograph of free-swimming young toadfish in water 1110

CXIII. (13) Larval toadfish, showing formation of color bands and disappearance of yolk 1110

METHODS OF STUDYING THE HABITS OF FISHES AND RECORDING THEIR LIFE HISTORIES:

Plate CXIV. (1) Water glass designed for observation or photography of objects under water. (2) Two-foot water glass supported on four legs and provided with screen, as used for studying and photographing lampreys 1136

CXV. (3) Reflecting water glass. (4) Male of common shiner, photographed in aquarium out of doors 1136

CXVI. (5) Photograph of nest of black bass, taken with aid of screen, camera above water. (6) Brook lampreys on nest, photographed through water glass in running water 1136

CXVII. (7) Galvanized iron box with plate-glass front, designed to contain camera when used under water. (8) Photograph showing method of using reflecting camera when inclosed in water-tight box for subaquatic work 1136

CXVIII. (9) Photograph of nest of a horned dace, taken with reflecting camera and by aid of a cloth screen. (10) Male and two females of horned dace, photographed in aquarium out of doors 1136

Facing page.

METHODS OF STUDYING THE HABITS OF FISHES AND RECORDING THEIR LIFE HISTORIES—Continued.

Plate CXIX. (11) Male horned dace picking up a stone. (12) Male horned dace about to drop a stone which it carries in its mouth. (13) Male horned dace which has just dropped a stone but has mouth still open. (14) Male horned dace pushing along the bottom a stone too big to carry........ 1136

CXX. (15) Photograph of dace in the act of spawning. (16) Male and female of horned dace just after completion of spawning act.................. 1136

INTERNAL PARASITES OF THE SEBAGO SALMON:

Plate CXXI. (1 to 6) Anatomical details of *Azygia sebago*. (6 to 10) Anatomical details of *Sparganum sebago*.................................... 1194

STRUCTURE AND FUNCTIONS OF THE EAR OF THE SQUETEAGUE:

Plate CXXII. (1 to 4) Anatomical details of ear of squeteague........................ 1224

AN INTENSIVE STUDY OF THE FAUNA AND FLORA OF A RESTRICTED AREA OF SEA BOTTOM:

Plate CXXIII. Chart of Vineyard Sound and Buzzards Bay, showing depth and character of bottom at dredging stations................................ 1264

CXXIV. Chart showing mean air and water temperature at Woods Hole for each day of the year.. 1264

VOLUMETRIC STUDIES OF THE FOOD AND FEEDING OF OYSTERS:

Plate CXXV. Oyster with filter apron, for study of feeding.......................... 1308

PLAN FOR AN EDUCATIONAL EXHIBIT OF FISHES:

Plate CXXVI. Typical synoptic case used in "corridor arrangement" for exhibition of fishes.. 1340

CXXVII. Section showing gill arches and pharyngeal teeth of the channel bass, illustrating kind of alcoholic material to be used as accessory anatomical exhibit.. 1340

CXXVIII. Mounted and painted skin of long-nosed gar.......................... 1340

CXXIX. Mounted and painted skin of yellow perch............................ 1340

CXXX. One of the cases devoted to the perch group, showing methods of utilizing colored plates and labels.. 1340

CXXXI. General label defining class Pisces.................................. 1340

CXXXII. A corner in the fish corridor.. 1340

CXXXIII. A typical case illustrating arrangement of specimens and method of indicating classification.. 1340

CXXXIV. A typical case, showing character of material to be used.................. 1340

CXXXV. One of the shark cases.. 1340

CXXXVI. Case devoted to the trout group...................................... 1340

CXXXVII. A portion of the case devoted to the Haplomi.......................... 1340

CXXXVIII. Method of treating large specimens to form frieze above cases........... 1340

CXXXIX. Type of label describing a life habit................................. 1340

CXL. Method of treating small fishes.. 1340

CXLI. A method of mounting a single specimen................................ 1340

METHOD OF PREPARING FISHES FOR MUSEUM AND EXHIBITION PURPOSES:

Plate CXLII. Reproductions from photographs of models of black bass, catfish, and lumpfish.. 1355

THE UNITED STATES BUREAU OF FISHERIES:

Plate CXLIII. United States Commissioners of Fisheries.............................. 1367

CXLIV. Headquarters of the Bureau of Fisheries, Washington, D. C. Superintendent's residence at a New England trout station................ 1370

CXLV. Marine hatchery and laboratory, Woods Hole. Residence at the marine station, Woods Hole, Mass.. 1374

The United States Bureau of Fisheries—Continued. Facing page.

Plate CXLVI. Collecting cod eggs on a fishing vessel. Open-air salmon-rearing troughs, Craig Brook, Maine.... 1376
CXLVII. Artificial spawning pond and raceway used in culture of rainbow trout. Interior of a typical trout hatchery.... 1378
CXLVIII. A fish transportation car. Interior of a fish transportation car.... 1382
CXLIX. Deep-sea exploring steamer Albatross.... 1384
CL. Trial fishing on the Albatross. Marine biological laboratory at Beaufort, N.C.... 1386
CLI. Alaskan fish traps and runs used by natives on Chilkoot stream. Salmon trap in an Alaskan river.... 1392
CLII. A Penobscot River salmon weir. Largest seine in the world.... 1396
CLIII. Catching and sorting the brood fish at a trout-cultural station in the Rocky Mountains. Stripping and fertilizing trout eggs.... 1400
CLIV. Salmon hatchery at Baird, California.... 1404
CLV. Fisheries steamer Fish Hawk. Main deck of steamer Fish Hawk, equipped for shad hatching.... 1408
CLVI. Fishery schooner Grampus. The fresh-fish fleet at T Wharf, Boston.... 1412

TEXT FIGURES—PART I.

International regulations of the fisheries on the high seas: Page.

Map showing area delimited by the North Sea Convention of 1882.... 117
Map showing territory covered by the Anglo-Denmark Convention of 1901.... 123
Map showing area designated in the award of the Fur-seal Arbitration Tribunal.... 129

A method of lobster culture:

Fig. 1-3. Larval lobsters, lateral view.... 224
4-7. Larval lobsters, dorsal view.... 225

A process for preserving the pearl-oyster fisheries:

Fig. 1. Plan of tray to contain pearl oysters for radiographing.... 309
2. Longitudinal section of tray shown in figure 1.... 309
3. Conveyer to substitute for tray shown in figures 1 and 2.... 310

Goldfish and their culture in Japan:

Typical forms of goldfish tails.... 384

Commercial sponges and the sponge fisheries:

Fig. 1. Hook used by the sponge fishermen of Florida.... 436
2. Dredge, or gangava, used in Mediterranean sponge fisheries.... 487
3. Section of dredge frame, showing bend of iron bar at ends.... 488
4. Transverse struts sometimes used between bars of dredge frame.... 488

A practical method of sponge culture:

Fig. 1 and 2. Showing insulated attachment for lead-covered lines supporting sponge cuttings.... 562
3. Needles used for threading cuttings on supporting wires.... 567
4. Diagram showing average rate of growth of sponges from cuttings of various sizes at Anclote Key.... 571
5. Diagram showing average rate of growth of sponges from cuttings of various sizes at Sugar Loaf Key.... 572
6. Diagram showing comparative increase in volume of an entire sponge and of the aggregate of cuttings from sponges of equal volume.... 575
7. Diagram showing percentages of mortality among different lots of sponges grown from cuttings at Sugar Loaf Key and Biscayne Bay.... 577

A PLAN FOR PROMOTING THE WHITEFISH PRODUCTION OF THE GREAT LAKES: Page.
Fig. 1. Map of Lake Superior, showing whitefish area 656
2. Map of Lake Michigan, showing whitefish area 657
3. Map of Lake Huron, showing whitefish area 658
4. Map of Lake Erie, showing whitefish area 659
5. Map of Lake Ontario, showing whitefish area 660

TEXT FIGURES—PART 2.

FISH-CULTURAL PRACTICES IN THE BUREAU OF FISHERIES:
Fig. 1. Clark-Williamson trough 711
2. Plan of barricade in Phinney Creek, near Birdsview, Washington 730
3. Front elevation of barricade shown in figure 2 730
4. Side elevation of barricade shown in figures 2 and 3 731
5. Section on line A–A of figure 2 731
6. Detail showing method of fastening racks 731
7. Atkins-Dinsmore shipping case, longitudinal section 744
8. Same, plan 744
9. Same, cross section 745
10. Argentine shipping case, section 748
11. Same, plan 749
12. German-Chile shipping case, longitudinal section 751
13. Same, plan 751
A NEW PRINCIPLE OF AQUICULTURE:
Diagram of houseboat and floats [hatching and rearing apparatus] 766
A METHOD OF CULTIVATING RAINBOW TROUT:
Diagram 1. Plan of ponds and spawning race 785
2. Spawning race, sectional views 786
3. Suggested arrangement of stream 786
APPARATUS AND METHODS AT MARINE HATCHERY, FLÖDEVIG, NORWAY:
Fig. 1. Plan of Flödevig hatching station 802
2. Spawning pond, plan 803
3. Same as figure 2, showing sections 803
4. Device for installation of egg collector 805
5. Same as figure 4, showing section 805
6. Hatching apparatus 806
7. Incubator 807
8. Mode of fastening incubator 807
PROPAGATION AND PROTECTION OF THE RHINE SALMON:
Fig. 1. Diagram illustrating sizes of salmon ascending the Rhine 822
2. Diagram showing ascent of Rhine salmon in different months 823
CULTIVATION OF THE TURBOT:
Fig. 1. Early development of the turbot 864
2. Apparatus for hatching turbot 867
TREATMENT OF FISH-CULTURAL WATERS FOR REMOVAL OF ALGÆ:
Figs. 1 and 2. Apparatus for regulating flow of copper solution 877
A DEVICE FOR COUNTING YOUNG FISH:
Measure by means of which to count young fish 1003
A METHOD OF MEASURING FISH EGGS:
Fig. 1. Metal trough for use in determining diameter of eggs 1011
2. Portion of diagram showing method of finding number of eggs per liquid quart 1014
AN IMPROVEMENT IN HATCHING AND REARING BOXES:
Fig. 1–3. Design of proposed hatching and rearing box 1021

DEVICES FOR USE IN FISH HATCHERIES AND AQUARIA: Page.
Fig. 1. Design for artificial pond with siphoid outlet 1027
2. A siphoid outlet for hatching and rearing troughs 1029
3. Apparatus for cleaning hatching or rearing troughs 1031
4. Cleaning device for ponds and aquaria 1032
5. Oxygenator and vacuum producer 1033
6. Scraper for preparing fish food 1035
FISHWAYS:
Fig. 1. Roberts 1045
2. Smith 1045
3. Wheeler 1045
4. Steck 1046
5. Foster 1046
6. Rogers 1046
7. Bracket 1046
8. Swazey 1047
9. Brewer 1047
10. Shaw 1047
11. Atkins 1048
12. Richardson 1048
13. Hockin 1049
14. Cail 1049
15. McDonald 1050
16. McDonald 1050
17. Caméré 1051
18. Kirk 1051
19. Recken 1052
20. Improved Cail 1053
21. Adaptation of improved Cail fishway, constructed of concrete 1056–1057
HABITS AND LIFE HISTORY OF THE TOADFISH, OPSANUS TAU:
Diagram showing adhesive disk of toadfish egg 1080
METHODS OF STUDYING THE HABITS OF FISHES:
Fig. 1. Longitudinal section of reflecting water glass 1121
2. Reflecting camera, shown in section 1123
3. Nest of horned dace, diagram in section 1126
4. Diagram showing ceremonial behavior of horned dace 1128
5. Male and female horned dace during spawning act 1130
AN INTENSIVE STUDY OF THE FAUNA AND FLORA OF A RESTRICTED AREA OF SEA BOTTOM:
Fig. 1. Map showing Woods Hole region and adjacent portions of New England coast 1237
2. Chart showing temperature throughout Buzzards Bay and Vineyard Sound in August 1238
3. Chart showing temperature throughout Buzzards Bay and Vineyard Sound in March 1239
4. Chart showing density throughout Buzzards Bay and Vineyard Sound in August 1240
5. Local distribution of the gastropod mollusk *Tritia trivittata* 1241
6. Local distribution of the polychætous worm *Nereis pelagica* 1242
7. Local distribution of the polychætous worm *Clymenella torquata* 1243
8. Local distribution of the bivalve mollusk *Yoldia limatula* 1244
9. Local distribution of the sertularian hydroid *Thuiaria argentea* 1245
10. Local distribution of the common skate, *Raja erinacea* 1246
11. Local distribution of the "window-pane" flounder, *Lophopsetta maculata* 1247
12. Showing localities at which the oyster, *Ostrea virginica*, or its shells, were taken 1248
13. Local distribution of the bivalve mollusk *Venericardia borealis* 1249
14. Local distribution of the actinian *Alcyonium carneum* 1250

AN INTENSIVE STUDY OF FAUNA AND FLORA OF A RESTRICTED AREA OF SEA BOTTOM—Continued. Page.
Fig. 15. Local distribution of the "whelk," *Buccinum undatum* 1251
16. Local distribution of the common scallop, *Pecten gibbus borealis* 1252
17. Local distribution of the "smooth" or northern scallop, *Pecten magellanicus* 1253
18. Local distribution of the common purple sea-urchin, *Arbacia punctulata* 1254
19. Local distribution of the green sea-urchin, *Strongylocentrus dröbachiensis* 1255
20. Local distribution of the common starfish, *Asterias forbesi* 1256
21. Local distribution of the purple starfish, *Asterias vulgaris* 1257
22. Local distribution of the "boat shell," *Crepidula fornicata* 1258
23. Local distribution of *Crepidula convexa*, a smaller species than the preceding 1259
24. Local distribution of the hermit crab *Pagurus longicarpus* 1260
25. Local distribution of the hermit crab *Pagurus pollicaris* 1261
26. Local distribution of the hermit crab *Pagurus annulipes* 1262
27. Local distribution of the hermit crab *Pagurus acadianus* 1263

GASES DISSOLVED IN THE WATERS OF WISCONSIN LAKES:
Fig. 1. Sketch map of Wisconsin, showing lake districts 1276
2. Lake Mendota. Chart showing vertical distribution of gases, carbonates, and temperature, January 26, 1906 1277
3. Lake Mendota. Same, February 25, 1906 1278
4. Lake Mendota. Same, March 29, 1906 1279
5. Lake Mendota. Same, April 8, 1906 1280
6. Lake Mendota. Same, May 4, 1906 1281
7. Lake Mendota. Same, May 22, 1906 1281
8. Lake Mendota. Same, July 2, 1906 1282
9. Lake Mendota. Same, August 1, 1906 1283
10. Lake Mendota. Same, October 8, 1906 1284
11. Lake Mendota. Same, October 11, 1906 1285
12. Green Lake. Same, October 4, 1906 1286
13. Lake Geneva. Same, September 26, 1907 1287
14. North Lake, east part. Same, July 30, 1906 1288
15. Thousand Island Lake. Same, August 13, 1907 1289
16. Stone Lake. Same, August 22, 1907 1289
17. Beasley Lake. Same, August 4, 1908 1290
18. Otter Lake. Same, August 4, 1908 1290
19. Silver Lake. Same, August 21, 1907 1291
20. Hammills Lake. Same, August 17, 1908 1291

VOLUMETRIC STUDIES OF THE FOOD AND FEEDING OF OYSTERS:
Fig. 1. Design of water-specimen cup, elevation 1300
2. Same, section 1300
3. Same, cross section at A, figure 2 1301
4 and 5. Same, details of tripping device 1301
6. Apparatus for extracting contents of alimentary tract of oysters 1305

PLAN FOR AN EDUCATIONAL EXHIBIT OF FISHES:
Fig. 1. Plan of fish hall in American Museum of Natural History, illustrating "corridor method" of arranging cases 1320
2. Example of family label 1321
3. Example of popular label for individual specimens 1322
4. Example of descriptive case-label defining a suborder 1324
5. An accessory label to illustrate a biological phenomenon 1325
6. Plan showing hall adapted to the "alcove arrangement" of cases 1326
7. Diagram of fish case to be used in hall with "alcove arrangement" 1327
8. Plan illustrating "gallery arrangement" of fish exhibits 1328
9. Sketch illustrating combination of pictorial fish groups with synoptic method of exhibition 1329

FISH-CULTURAL PRACTICES IN THE UNITED STATES BUREAU OF FISHERIES

By John W. Titcomb

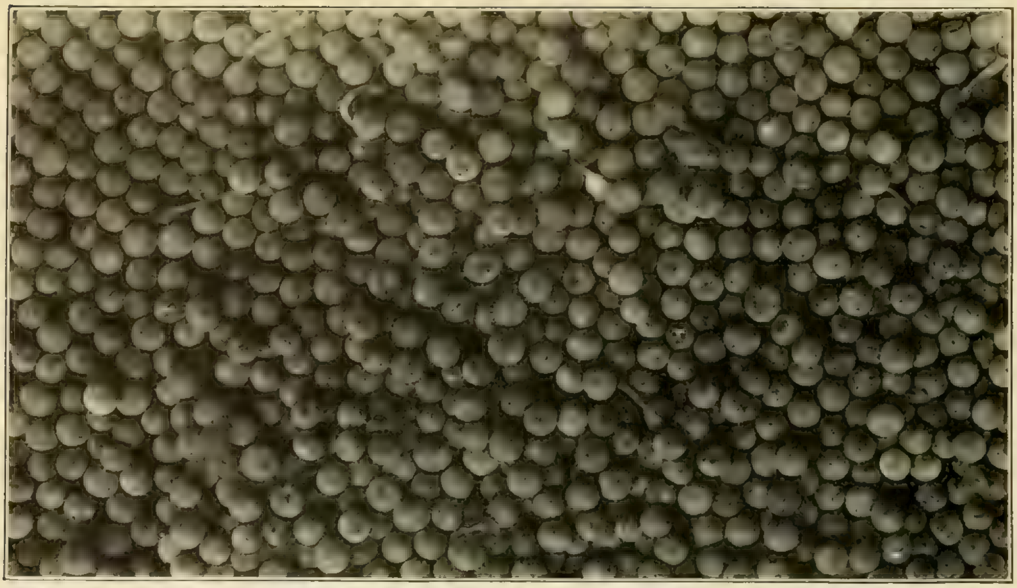
Assistant in Charge of the Division of Fish Culture

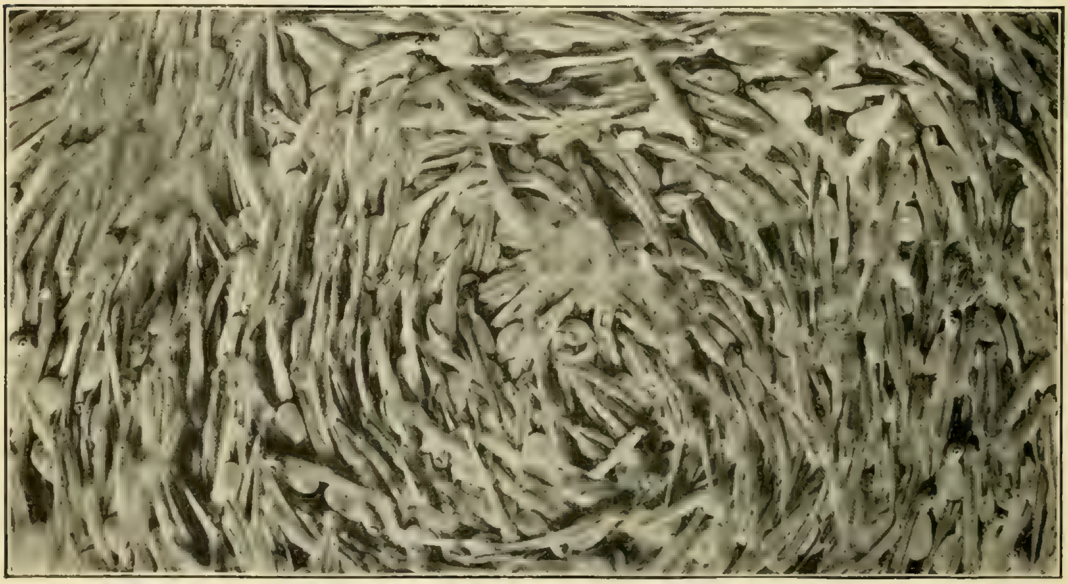
Address before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

B. B. F. 1908—Pt 2—2

CONTENTS.

	Page.
Resources of the Bureau	699
Extent and general methods of the work	699
River fishes of the east coast	702
Shad	702
White perch	704
Yellow perch	705
Striped bass	706
Fishes of the Great Lakes	707
Whitefish	707
Pike perch	708
Lake trout	710
The brook trouts, chars, and eastern salmons	712
Spawntaking in Colorado	713
Rearing methods	714
Special devices applied at trout stations	716
Atlantic salmon	718
Pond culture	719
The ponds	719
Food for the adult fishes	720
Artificial nests	720
Number of brood fish	721
Collecting the young fish	722
Rescue of fishes from overflowed lands	724
The Pacific salmons	725
Barricades and traps to intercept spawning runs	726
At Baird, Cal	726
At Battle Creek, Cal	728
At Birdsview, Wash	728
Taking and hatching the eggs	732
Seining operations and spawntaking at California stations	732
Local practices in different regions	735
Marine fish culture	736
Cod, pollock, and flatfish	736
Lobsters	737
Measuring and counting the eggs and fry	739
Transportation of eggs	741
Usual style of packing case	742
Adaptations and variations of method	742
Argentine case	747
German-Chile case	750
Transportation of fish	752
Distribution and planting of commercial fishes	755
Distribution of game fishes	756





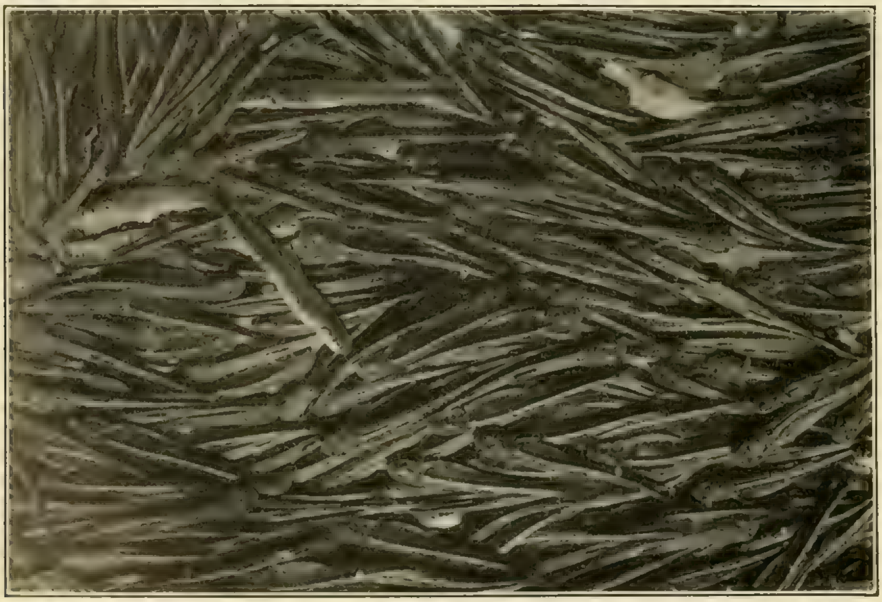


FIG. 1.—Brook trout eggs on tray, just beginning to hatch.
FIG. 2.—Brook trout fry in trough, sac stage.
FIG. 3.—Brook trout fry, sac nearly absorbed, ready to feed.
Figures about natural size. See also figure 12, plate LXXXII.

FISH-CULTURAL PRACTICES IN THE UNITED STATES BUREAU OF FISHERIES.[a]

By JOHN W. TITCOMB,
Assistant in Charge of the Division of Fish Culture.

RESOURCES OF THE BUREAU.

The fish-cultural work of the United States Bureau of Fisheries, administered from headquarters at Washington through the Division of Fish Culture, is conducted by means of numerous hatching stations located in various parts of the country, including Alaska. There are thirty-two such stations recognized for administrative purposes. Auxiliary to these are numerous field stations, some of them equipped as hatcheries and in operation throughout the year, others used only during the spawning season of the fishes they are concerned with. The land owned by the Bureau at its fish-cultural stations has an aggregate area of 12,000 acres, valued at $225,000. The improvements on this land in buildings, ponds, and special equipment represent an investment of about $1,000,000. The Division of Fish Culture has 225 civil-service employees, whose salaries aggregate approximately $200,000; while there is an annual appropriation of $275,000 for the maintenance and operation of stations, including the employment of temporary laborers and assistants in fish-cultural work.

It will be my endeavor to allude to some of the more important phases of the fish-cultural work which these resources make possible, and to explain more fully than would otherwise be permissible features of the work in which recent changes in methods or equipment have not heretofore been so fully illustrated or described.

EXTENT AND GENERAL METHODS OF THE WORK.

During the fiscal year 1908 the Bureau distributed fish and eggs to the number of 2,871,456,280. The table accompanying gives an idea of the extent of the work for a series of years.

[a] This paper as read before the International Fishery Congress was illustrated by lantern slides, to supply the absence of which in publication the text has been amplified.

AGGREGATE OF ADULT FISHES, YEARLINGS, FRY, AND EGGS DISTRIBUTED BY THE BUREAU OF FISHERIES FROM 1872 TO 1908.

Species.	1872–1897.	1898–1908.
Shad	1,379,247,350	1,381,209,594
Salmons	168,073,769	1,050,738,390
Trouts	70,499,665	506,781,985
Whitefish and cisco	1,579,923,409	3,889,418,135
Basses	7,212,403	34,702,267
Perches	796,027,818	5,056,995,274
Cod, haddock, pollock, etc	520,223,000	2,241,063,000
Flounder	94,522,019	1,921,625,000
Other fishes	47,446,864	7,217,024
Lobster	387,989,712	1,182,471,440
Total	5,051,166,009	17,272,222,109

The first column represents the output of the United States Fish Commission from its inception to the beginning of the present Commissioner's administration, a period of twenty-six years. The second column represents the output for the subsequent period of eleven years. The total operating expenses of the entire eleven years, 1898 to 1908, did not exceed those of the preceding twenty-six years, while the output has been more than trebled. About 50 species of fishes are now handled.

The results of fish culture, as shown by numerous replenished waters and by actual returns in fish, might easily be made the subject of a lengthy discourse, but for present purposes will be alluded to only incidentally. A marked evidence of success may be noted in the constantly increasing demand for young fish to plant. Notwithstanding the fact that the bureau, by the increase of its facilities and by progressive methods, has steadily increased its output, the demand of the public for fish has increased therewith until in some lines of work, notably the production of the basses, crappies, other sunfishes, and the catfishes, it is greater than can be met with present means.

It is a point to be emphasized that the fish-cultural work of the Bureau is of two classes with respect to its economy. Many of the most valuable food fishes, being in their prime for market purposes just prior to the spawning season, are most extensively captured at the very time they should be spared for the perpetuation of their kind. Whenever possible, the Bureau secures the eggs of these fish from the fishermen. Fully 96 per cent of all the eggs collected and hatched by the Bureau are taken and fertilized from fishes destined to the market, and this without detracting from the value or edible qualities of the parent fish.

The collection of fish eggs under these conditions is to be distinguished from the work which utilizes the eggs of fish that have reached their spawning grounds and which it is customary to capture for the express purpose of obtaining and fertilizing their eggs. The latter is fish culture in the usual sense—extensive

increase of the numbers of young by protecting the eggs and providing the most favorable conditions for hatching. The other is fish culture also, but in addition to conservation of a resource that would otherwise be unavailed of.

Some of the freshwater species, valued chiefly as game fishes although marketed also, are cultivated by confining them under conditions which will secure the maximum reproduction by natural processes. Practically all of the important commercial fishes, however, can be propagated, and much more numerously, by stripping them of eggs and milt by hand and incubating the fertilized eggs in hatcheries. It is with these that the Bureau is most largely concerned, their numbers being nearly 98 per cent of the entire output of the hatcheries.

There are some variations in the methods of spawntaking, according to species, but in general the operation consists in expelling the eggs by a gentle pressure of the thumb and forefinger along the walls of the abdomen, the strokes being continued until all ripe eggs have been secured. The fish is usually grasped near the head, and to hold it firmly may be pressed against the body of the spawntaker. The receptacle into which the eggs are expelled is usually a 6-quart milk pan which has been dipped into the water and then emptied, thus leaving it slightly moist. Other forms of receptacles, such as marbleized or porcelain-lined pans or wooden vessels are sometimes used where the eggs are especially adhesive. The milt is obtained by the same process as the eggs, and applied to the latter in the pan used to receive them from the fish.

The hatching processes are, generally speaking, of three classes with respect to equipment, determined primarily by the specific gravity of the eggs. Heavy eggs, such as those of the trouts, salmons, and the grayling, are incubated in wire-bottom trays or wire baskets set in troughs of running water. The mesh of the wire is of size to suit the size of egg and to permit the young fish as they hatch to drop through into the trough. The troughs are usually plain open boxes varying in length from 12 to 16 feet and in depth from 4 to 12 inches, to suit conditions. An arbitrary width of 14 inches, inside measure, has been adopted, uniformity in width being desirable for economy in interior equipment. For handling large quantities of eggs the troughs are frequently provided with either permanent or removable partitions to regulate the direction of the current of water through the eggs. Thus they may be converted into so-called Williamson and Clark-Williamson types of troughs.

Semibuoyant eggs, such as those of the whitefish, pike perch, shad, yellow perch, and white perch, are usually hatched in glass jars. The styles of jar are in general two –closed top and open top, the McDonald Universal hatching jar being of the former pattern, the Chase, McDonald open-top, and Downing being typically the latter.

The principles of the McDonald Universal (patented) jar are familiar.[a] By substituting for the closed top a screw-cap rim to which has been soldered a pitcher-like spout, the Universal or automatic jar may be converted into an open-top jar and thus is the preferable equipment at hatcheries where both closed and open-top jars are required. As an open-top jar it is operated the same as the Chase and Downing jars. At hatcheries where only open-top jars are used the Downing pattern is preferred.

RIVER FISHES OF THE EAST COAST.

SHAD.

The most important fish of the east-coast streams, the shad, is the especial object of three hatcheries—at Havre de Grace, Md., on the Susquehanna River; at Bryans Point, Md., on the Potomac; and at Edenton, N. C., on Albemarle Sound. The steamer *Fish Hawk* is also equipped as a hatchery, and utilized at such points as may be advantageous.

As all of the eggs for the hatcheries are obtained from market fish, the shad work is primarily conservation. The exhaustive fishing at the mouths of the rivers leaves, moreover, so few fish to reach the spawning grounds that the fishery is now, in the northern streams, entirely dependent upon the hatcheries, which are themselves interfered with by the scarcity of ripe fish. Recent legislation in North Carolina has widely restricted fishing so that there has been a notable improvement of conditions in that region, and much larger collection of eggs at Edenton.

Curiously enough shad are seldom caught in ripe condition during daylight until late in the afternoon. Thus the fishermen's catch of the late morning or early afternoon is not available for the rescue work of the spawn taker. But on the approach of evening during the spawning season of the shad, the Bureau's agents may be found leaving their camps to embark preparatory to being distributed on the various fishing boats or to fishing shores where shad in ripe spawning condition are to be had.

In the collection of shad eggs the fishermen often personally manipulate the ripe fish for eggs and milt, and it is customary for the Bureau to provide all such men with the usual spàwntaker's equipment of pans, buckets, etc. It is always necessary to employ a force of experienced men to go among the fishermen, to see that the eggs of all ripe fish are saved, fertilized, and properly cared for until they reach the hatchery. It may not be amiss to say that spawntakers should also be experienced boatmen, not only as a matter of safety to themselves, but because the fishermen are averse to allowing inexperienced men in their boats.

[a] Manual of Fish Culture, revised edition, 1900, p. 138. Published by U. S. Bureau of Fisheries.

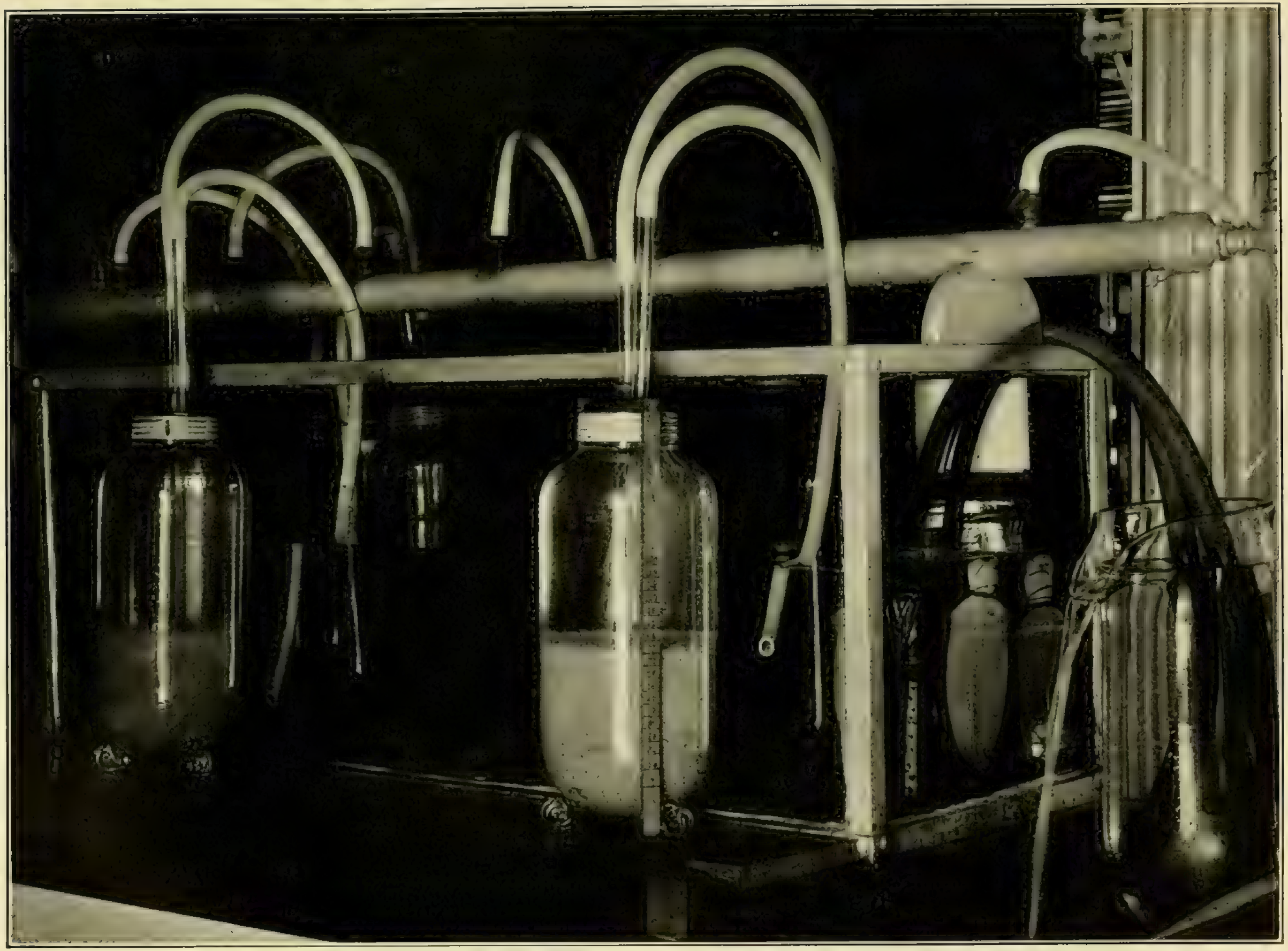


FIG. 4.—Hatching equipment for shad and other semibuoyant eggs. Over the inner ends of the tubes which serve as outlet for the aquarium is an elongate wire frame, screened with cheese cloth for white perch and other very small fry, with wire cloth for shad. (See reference on p. 705.) The jar at the right (Downing pattern) is here used, as might be any other open vessel, to maintain the desired water level in the aquarium, the outlet tubes siphoning directly into this. The scale attached to the jar (McDonald universal) in the center of the picture is the measuring device referred to on page 740.

The treatment of eggs of the shad after the milt has been applied is in substance as follows:

About half a pint of water from the river is dipped into the pan, which is then given a slow rotary motion until the milt is thoroughly mixed with the eggs. This pan with its contents is then set aside and another is used in a repetition of the process. After all the stripping has been done the milt is washed from each pan of eggs by dipping water from the river and pouring it off, repeating until the milky color of the water disappears. The pans of eggs, with about 1 pint of water in each, are then set aside, and after fifteen or twenty minutes it will be noticed that the eggs are absorbing the water. A little more water must then be added from time to time until they have fully expanded, which usually requires from forty to sixty minutes, but varies somewhat with the water temperature. When fully water-hardened, the eggs feel like shot to the touch of the fingers, and now, less sensitive to concussion, are ready to be transferred to the buckets in which it is customary to convey them to the hatchery.

En route to the hatchery it may be necessary every twenty or thirty minutes to replace the water on the eggs with water from the river in order to maintain an even temperature, the air on very cool nights affecting the water in the buckets to such degree as to injure the eggs.

The first thirty-six to forty-eight hours after arrival at the hatchery is the period of greatest mortality to the eggs, and until this has passed they are kept in open-top jars or in McDonald jars without tops, the water flowing through them being allowed to waste over the tops of the jars. The dead eggs being lighter than the live ones work toward the surface and are easily removed with a siphon of 1½-inch rubber tubing. The good eggs are then measured (by means of a device which will be described later) and their number is accredited to the fisherman from whom they were obtained. They are then put up for hatching in the McDonald Universal (i. e., closed-top) hatching jars, which are arranged on specially constructed tables in connection with rectangular glass aquaria or receiving tanks and subjected to a current of about 4 or 5 pints of water per minute at 8 pounds pressure, which is sufficient slightly to elevate the eggs from the bottom of the jar, thus giving the entire mass a slow revolving or boiling motion. The number of eggs to each jar is from 85,000 to 100,000. As the young fish emerge from the eggs they rise toward the surface, where they come in contact with the suction outlet tube of the jar and pass through it with the waste water to the collecting tanks. From this they may be removed to the distributing cans by means of a ½-inch rubber siphon. Another method of removing them is to dip them from the aquaria after siphoning off a portion of the water. By this method, emptying an equal number of dippers of fry into each can, it is possible to quite equally distribute the total number to be removed.

WHITE PERCH.

With the decadence of the valuable shad fishery there has arisen a demand for the artificial propagation of the white perch (*Morone americana*), and this work has been extensively conducted at the mouth of the Susquehanna River during the past four seasons in connection with the hatching of shad. Like shad culture, the propagation of white perch is purely the conservation of eggs which would otherwise go to market in the parent fish.

The spawning season in the latitude of the Bureau's station at Havre de Grace, Md., is from the middle of April to the latter part of May, the time varying with the character of season. The eggs are taken and fertilized by the usual dry method, the work being performed ordinarily by the fishermen. Owing to the adhesiveness of the eggs it is preferable to strip them into marbleized or porcelain-lined pans.

As with shad and other spring spawning fishes, the white perch spawns on a rising temperature, ripe fish being taken first when the temperature is about 47°. However, the eggs seem to produce better results when hatched in water of a higher temperature. At about 60° F. they hatch in forty-eight to fifty-two hours, while at 68° to 70° they hatch in twenty to twenty-four hours. They are sensitive to sudden drops in temperature, and although at 58° or 60° about 75 per cent of the eggs produce vigorous fry, at 50° or lower few if any eggs or fry survive. In one case eggs taken at 56° and held for twenty-four hours, after which the temperature dropped to 46°, finally hatched at a temperature of 54°, producing a fair percentage of fry. Observations thus far made indicate that eggs taken at mid-day or soon after mid-day produce better results than those taken earlier in the morning, although the reason has not been ascertained.

After being held for from six to twelve hours in jars without tops, white perch eggs are incubated and hatched in McDonald automatic jars on shad tables in the same manner as shad eggs. As they are especially liable to fungus, a good circulation is particularly important, and it is inadvisable to carry more than one-fourth capacity to a jar, or from 800,000 to 1,000,000. The eggs are comparatively heavy, and for this additional reason require more water circulation than is needed for shad, or 2½ to 3 quarts per minute. It is customary to reduce the flow about one-half during the last few hours before hatching, in order that fungussed masses and attached good eggs may not be carried out into the receiving tank.

When undeveloped the eggs are very white and hard, and it is difficult for the novice to tell the live ones from the dead. Some that apparently are dead suddenly eye and hatch, while, on the other hand, some apparently of good quality frequently fungus and prove a total failure. By examining in a glass

tube, with which a few at a time may readily be removed from the jars, it is usually possible to distinguish the live eggs at any stage of development.

The eggs average 29 to the linear inch when first expelled and 28 to the inch after being water hardened. They are usually measured into the jars with a 1-quart apothecary's graduate, and are computed at 1,600,000 to the quart.

To guard against the escape of very small fry from the receiving aquarium the usual waste water outlet is closed, and the water is carried off by means of one or more siphons, the suction ends being provided with wire cages covered with two or three thicknesses of cheese cloth. To regulate the level of the water in the receiving tank the outlet ends of the siphons empty into an adjacent receptacle, usually a hatching jar, the rim of which is at the desired water level.

YELLOW PERCH.

It is feasible, and under some conditions desirable, to expel and fertilize yellow perch eggs artificially, but under proper conditions practically all naturally deposited eggs are fertilized. For this reason the Bureau's work largely consists in the incubation of the naturally deposited eggs obtained from fish confined in crates for the purpose, and to some extent by collection of natural spawn in marshes where left by receding waters.

It has been found that the eggs can be hatched in almost any kind of container through which water is flowing—open troughs, open jars, shad aquaria, etc.—but careful experiments indicate that the McDonald open-top and the Downing jar are preferable to other kinds of equipment, the Downing jar possessing the advantage of greater capacity. It will hold 130,000 to 150,000 eggs, and when thus incubated the eggs are subjected to a water circulation of about 1 pint per minute.

As little has been published on the methods of culture of this fish, the data of the superintendent in charge of the yellow perch operations at Bryans Point, Md., will be given in some detail:

Here the fish are purchased from commercial fishermen, are held in crates having comparatively tight bottoms, and allowed to spawn naturally. The crates are 8 feet long, 4 feet wide, and 2½ to 3 feet deep, and are placed in the mouth of a small creek tributary to the Potomac reached by tide water from the river. A small number of fish are also kept in a large tank at the hatchery, through which there is a constant flow of river water in connection with the regular station supply.

The collecting of fish begins about the middle of March or when the water temperature ranges from 34° to 37°. The water temperature in which spawning occurs ranges from 42° to 46°. In 1908 the first eggs were obtained March

21 in a water temperature of 46°. Practically all the fish had finished spawning on April 1, at which time the water temperature was 58°. The spawn is taken daily from the crates and transferred to the hatchery in buckets.

The eggs are comparatively heavy, and are slightly adhesive when first deposited. The period of incubation in a water temperature of 47° to 54° is ten to twenty days. The absorption of the yolk sac requires a period of eight days in a mean temperature of 54°. On the Potomac River the average number of eggs from fish of one-half pound weight is about 15,000.

When measured into the jars the eggs are computed at 100,000 to the quart. Actual measurements of 10 eggs average 1.662 millimeters or 0.065 inch in diameter, but on account of the peculiar gelatinous envelope of the egg, these individual egg measurements are of no use whatever in estimating the number in a given volume.

STRIPED BASS.

At Weldon, N. C., is a field station for the propagation of the striped bass (*Roccus lineatus*). It has been operated for a number of years with rather negative results as to the number of eggs collected, but with experience of much value as suggesting lines of improvement in methods of manipulating ripe fish and the eggs.

The chief obstacles to successful work in the propagation of this fish are the difficulties of obtaining ripe spawning females in numbers sufficient to produce large results, and of obtaining a ripe male at the time a female is available. Penning the fish has not proved successful. The delicate nature of the eggs and the limited period of incubation—1½ days—are reasons for believing that they can not be successfully transported from the source of supply.

The McDonald automatic hatching jars have been somewhat successfully used at Weldon, but the sac fry of the striped bass are more tender than those of any other fish and it was found that many were injured in their passage to the aquarium through the rubber tube of the closed top. The style of jar was then changed to open top, and has given highly satisfactory results. An elongation of the pitcher mouth by means of a trough of canvas delivers the fry from the jar to the aquarium without friction and concussion. Owing to the buoyancy of the eggs less than one quart of water per minute is supplied to each jar and at time of hatching only about one pint. When water hardened the eggs are computed at 35,000 to the liquid quart and it is customary to incubate 80,000 in each McDonald jar.

In the latitude of Weldon, striped bass spawn in a temperature of 70° to 77°, the season being from the middle of April to early in June.

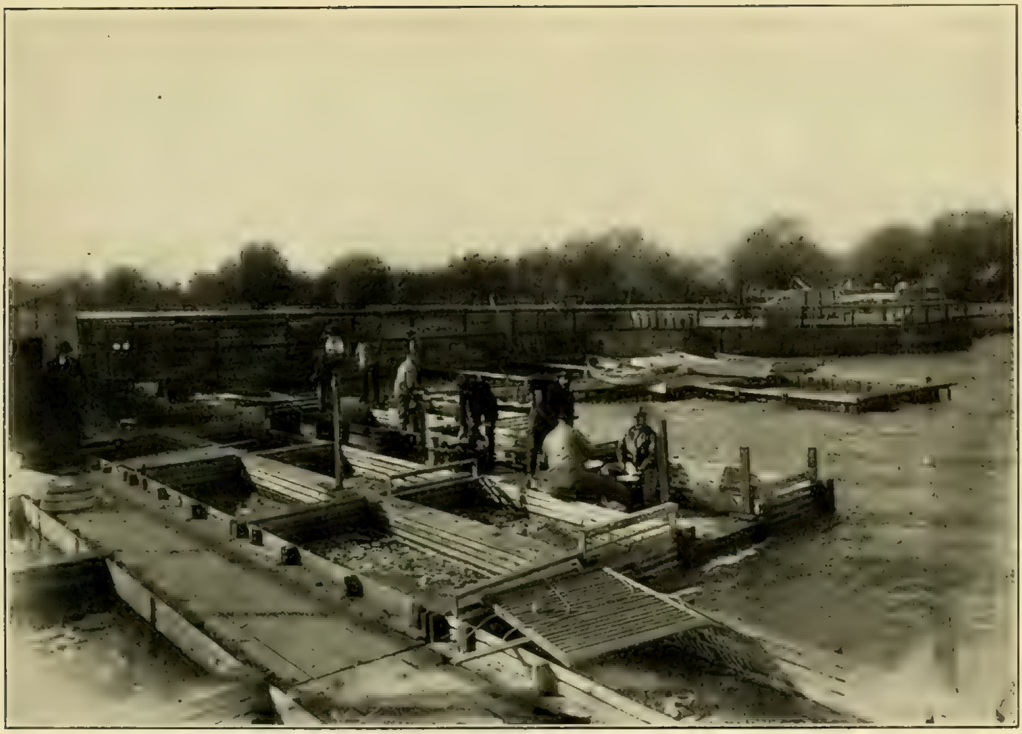


FIG. 5.—Spawntaking operations on the Detroit River, Michigan. Whitefish caught in commercial fishing are held in crates and pounds until ripe. The crates are provided with false bottoms, which may be raised for easier access to the fish.

FIG. 6.—Two men with dip nets are lifting fish from crates (male whitefish in one crate, females in another) into the tubs at the spawntaker's right. The pan of eggs is passed to the man at the extreme left, who "washes them up" before they are put into the neighboring tub for water hardening and removal to the hatchery. (Detroit River, Michigan.)

FISHES OF THE GREAT LAKES.

For the maintenance of the fisheries of the Great Lakes the Bureau operates hatcheries at Put-in Bay, Ohio, Northville, Mich., Duluth, Minn., and Cape Vincent, N. Y. At Cape Vincent the work consists largely in hatching and distributing the product of eggs received from other hatcheries, Lake Ontario not being a fruitful field for the collection of eggs.

WHITEFISH.

At Put-in Bay station in the fall of 1907 the collections of whitefish eggs reached a total of 336,000,000, the largest on record for any station.[a] In this locality the eggs are in large part obtained by direct purchase from the fishermen, who have expelled and fertilized them as they removed the fish from the nets. In addition it is customary to pen 8,000 to 10,000 fish in crates at points convenient to the base of operations. These fish are obtained from fishermen at a nominal price for use until after spawning, when they are returned to the fishermen to be marketed. As it has not been practicable to confine the fish successfully for a very long time, this procedure is not undertaken until they are nearly ripe, the total period of confinement from the beginning of the collection to the close being about three weeks.

The crates used for penning the fish are 16 feet long by 8 feet wide by 6 feet deep, and have a partition dividing each crate into two compartments 8 feet square by 6 feet deep. Each compartment is provided with a false bottom, which may be raised at will while the fish are being manipulated, and can be shoved down against the stationary bottom afterwards. For convenience in handling the crates are made "knock down," and thus can be easily removed from the water and used year after year. While in the water they are held in position by floats 52 feet long, the crates placed between them endwise, five crates forming a raft. Only 12 inches of the crates extends above the surface of the water. The rafts are held in place by stakes driven into the bottom of the bay. Of the total number of eggs collected about 25 per cent are taken from fish confined in crates.

Another important field station for the collection of whitefish eggs is in the Detroit River, where operations are conducted from the Northville (Mich.) station. Here the eggs are derived from fish caught for fish-cultural purposes by market fishermen who operate under permits issued by the Bureau. The fishermen are willing to incur all expenses of the collections, as well as the losses from penning, for the privilege of disposing of all the marketable fish after the Bureau has taken the eggs. Penning stations are located accessible to the seining

[a] Since this writing another spawning season has passed with a record for the Put-in Bay station of over 373,000,000 whitefish eggs.

grounds, and all fish are transferred to the crates before being spawned. Spawn-taking operations are conducted daily throughout the entire period while the fish are penned. About 75 per cent of all the females confined in crates yield good eggs; the remainder either cast their eggs in the crates, become plugged, or fail to ripen.

At the Put-in Bay station the Downing jar, an open-top glass vessel with pitcher lip, devised by the superintendent, has supplanted other forms of hatching jars. In each of these jars 4½ quarts of green eggs to 5¼ quarts of eyed eggs are subjected to a flow of 4 quarts of water per minute. The jars are arranged in so-called batteries, which are described in the Manual of Fish Culture elsewhere cited. The batteries at Put-in Bay are of the type known as single batteries, each having an independent water supply. They have some new features, notably, for economy in arrangement, the alternation in position of the jars in vertical rows, thus making it possible to bring the troughs more closely together. In the batteries at this station there are 1,692 jars and the flow of water through them is so economically arranged that only 330 gallons per minute is required when all are in operation. This type of battery is the one commonly used at the Bureau's stations, called single battery to distinguish it from the double battery at Detroit.[a] The Detroit hatchery is equipped with 1,487 Chase and Downing jars, and a total of 441 gallons of water is required when the entire battery is in operation.

At Cape Vincent station the battery is a single tier, but the arrangement of the jars is not so compact and the tiers are not so well set up as to economy in water supply, 492 jars requiring a total volume per minute of 123 gallons. At Swanton station a single battery of 606 jars requires a total volume of 227 gallons per minute. The batteries at Detroit and Put-in Bay are constructed entirely of wood; the battery at Cape Vincent was originally of wood, but as the troughs began to decay galvanized iron was substituted without removing the original stand on which the wooden troughs rested. At Swanton the supply troughs in the battery are also of galvanized iron, the first cost of which is more than for wood, but taking into consideration durability of material, may be considered more economical.

PIKE PERCH.

By methods similar to those pursued in the conservation of whitefish eggs, pike perch eggs also are extensively collected, the most important field, as with the whitefish, being within a 40-mile radius of the Put-in Bay station. Here and at other points on the Great Lakes the eggs are all obtained from ripe fish as caught, the penning of the pike perch by methods described for the whitefish having proved not feasible in the sheltered bays where such work might other-

[a] Manual of Fish Culture, p. 117.

wise be possible. The method of spawntaking at Put-in Bay is in general as follows:

On account of the adhesiveness of the eggs a wooden or fiber receptacle is used instead of the usual tin spawning pan. A liberal quantity of milt is applied, the mass is thoroughly stirred with a feather or with the bare fingers, and a little water is added. Then pan and contents are lowered into a keg, containing about 2 gallons of water, and the pan is carefully emptied. This process is repeated until the keg is about one-third full. The eggs are now left undisturbed until spawning operations are ended—not over two or three hours; then water is added, a little at a time, until the keg is nearly full. Some of the water is then poured off and more added, this process being continued until all the milt is washed off and the eggs are thoroughly water hardened.

The chief precaution during the water-hardening is this constant pouring off and addition of water. Care must be taken in pouring the water to have it fall not directly on the eggs but against the side of the keg. During this period the eggs must not be stirred, for the reason, it is said, that such motion tends to rupture them. It is also important to avoid exposure of the eggs to the air, since because of their adhesiveness they will form in a nearly solid mass. When they are sufficiently water-hardened they may be separated by gently loosening them with the bare hand. After separating them it is necessary to change the water frequently until they can be transferred to hatching jars.

The fact that pike perch spawn in the spring, while fall is the spawning season of the whitefish, makes it possible to utilize the same batteries and other hatching equipment for both species.

In order to overcome the adhesiveness of pike perch eggs and prevent their forming unwieldy masses, it was formerly considered necessary to use muck or starch in the water into which the eggs are placed immediately after fertilization. The use of muck has now been entirely abandoned and neither starch nor muck is used at Put-in Bay.

At Swanton, Vt., the pike perch is regarded as of more value as a game fish than for the maintenance of a commercial fishery. The hatchery is stocked with eggs taken from fish captured purely for fish-culture purposes from the waters of Missisquoi Bay and River. The conditions under which the eggs are taken are more favorable than those existing on the Great Lakes, it being possible to pen the unripe fish for a week or more while maturing, the penning crates being located in a current of water in the river. Delivery of the eggs at the hatchery is also more expeditious.

In the manipulation of eggs here the methods are somewhat different from those just described. After impregnation in the usual manner a little water is added and the eggs are left for five to eight minutes; then more water is added and the eggs are withdrawn carefully into half a bucket of water into which two

tablespoonfuls of ordinary corn starch have been thoroughly stirred. Here they are allowed to remain ten minutes. The bucket is then filled with clear water and the washing process begins, the water being replaced until only clear water remains with the eggs. They are then stirred continuously with the hands for a period of forty-five minutes, the bucket being at the beginning about one-third full of clear water, to which more is added during this time. At the end of the continuous stirring the worst period of adhesion is over and from that time on the eggs may be stirred and fresh water added every hour until they reach the hatchery. Here they are held in a tub of running water overnight, then screened, measured, and placed in jars on the batteries.

It will be noted that the two methods of manipulating the eggs are quite at variance. There are so many factors to be considered that it has not yet been decided which procedure is best.

Pike perch eggs require more care than do the eggs of any other species handled by the Bureau. When received they are usually massed together in lumps and must first be separated with the bare hands and passed through a screen of soft bobbinet before being placed in the jars. While in the jars they require constant attention and must be frequently separated, it often being necessary to take down individual jars several times and pass the contents through the bobbinet screen.

Although pike perch are found in ripe condition in water ranging from 38° to 60°, more eggs are taken in a temperature ranging from 38° to 50° than above 50°, and the higher temperature seems to be most favorable for hatching the maximum number of fry. Unfortunately, however, the water of the hatcheries is usually of the colder temperature in which the fish spawn, and a high percentage of fry has therefore been unattainable. An average production in fry of 50 per cent of the eggs taken may be regarded as very good.

LAKE TROUT.

The station at Northville, Mich., with its several other lines of fish culture, is also the principal center of the lake trout work, and has a record of over 58,000,000 such eggs in one season.[a] As the spawning season is short, however, and is at a period of the year when the fishermen, on account of rough weather, often can not set or take up their nets at will, the collection of eggs must necessarily vary in quantity and quality from year to year according to weather conditions.

The data for one season show the average weight per fish to have been 7.4 pounds; that 66 per cent of the catch of females yielded eggs; and that the eggs averaged two-thirds of a fluid quart per fish.

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[a] Since this writing another spawning season has yielded 71,000,000 eggs at the Northville station.

FIG. 7.—Interior of one wing of hatchery at Put-in Bay, Ohio, showing four batteries and the tanks (left foreground) into which the fry are carried by the flow from the jars.

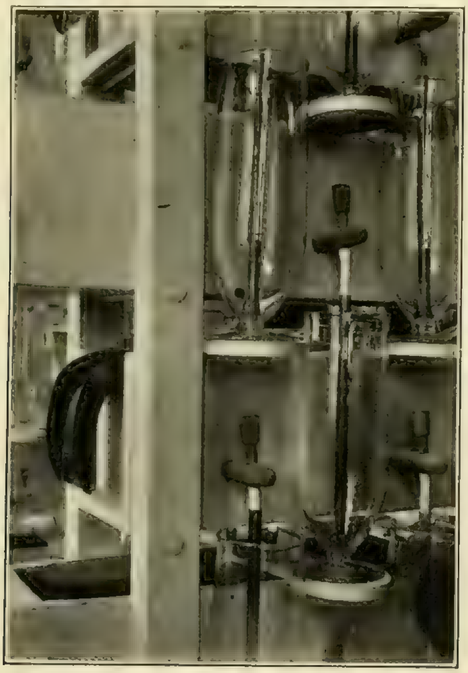

FIG. 8.—Downing jars set up for use on "battery" at Put-in Bay station, Ohio. The troughs into which the water flows from the pitcher mouth of the jars serve also to supply the jars in the next tier, by means of the wooden faucets, and there is a small overflow at alternate ends of each trough. This is the common equipment for hatching whitefish and pike perch.

The hatchery equipment for lake trout at Northville is the common form of wire tray, stacked in troughs of the Clark and Clark-Williamson types.[a] The collections in this region have increased so greatly in recent years, however, that they have outgrown the capacity of the hatchery, and it has been necessary to deepen some of the Clark-Williamson troughs to accommodate more trays during the eying period of the eggs. The deeper troughs are 15 feet long and 3½ feet wide, with a division through the center the entire length; the width therefore is that of a pair of troughs having a common bottom. The outside depth is 18 inches. Each of the deep troughs contains, besides the bulkhead, 15 compartments 19 inches by 10 inches by 16½ inches deep, with a capacity of 16 trays 18½ inches long by 9½ inches wide, on each of which may be placed, if crowded, 10,000 eggs. The total maximum capacity of each pair of

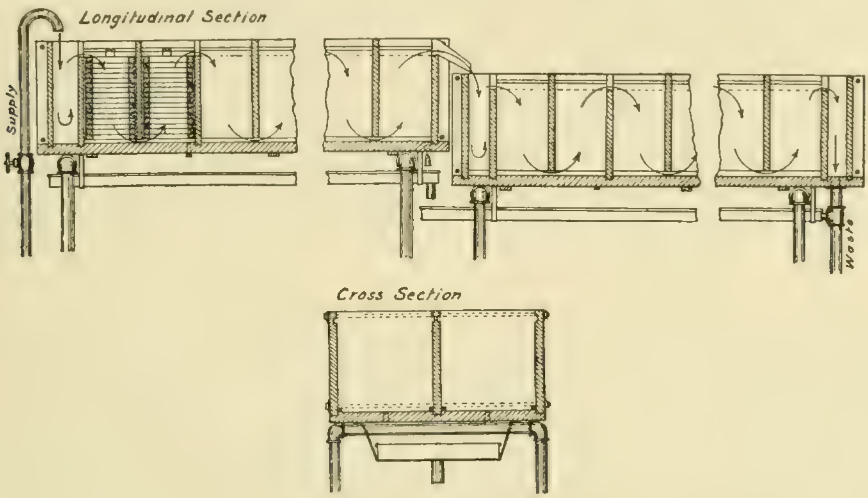

FIG. 1.—Clark-Williamson trough.

troughs is then 4,800,000. For best results, 8,000 eggs to the tray, or a total of 3,840,000 to each pair of troughs, is a proper number.

During incubation the eggs seem to do equally well in either up or down current of the Clark-Williamson troughs; at other stations where eggs are incubated in stacks of trays the Williamson type of trough is used.

As lake trout eggs are taken from fish that have been caught in nets hauled into fishing tugs by steam power, often during rough weather and frequently after the nets have been inaccessible for several days, the percentage of good eggs is not equal to that secured from most of the species manipulated. Consequently a large force of young women, who are more deft with their fingers than are men, are temporarily employed to pick over the eggs. A shallow trough with water flowing through it is provided for this work; in this trough, standing

[a] For full description of these troughs see Manual of Fish Culture, p. 97–99.

above the water on four short legs, are wire baskets, one for each egg picker, into which to throw the dead eggs. The farther side of each basket, to the picker's right, has a high back to stop the eggs as thrown from the tweezers, thus making it unnecessary for the eyes of the picker to follow each egg, and thereby facilitating the entire operation.

THE BROOK TROUTS, CHARS, AND EASTERN SALMONS.

For brook trout eggs (*Salvelinus fontinalis*) the Bureau depends largely upon commercial trout raisers, eyed eggs being obtained from them at lower cost than it is possible to collect from wild fish at most places or from brood fish maintained only for their eggs. About 8,000,000 eggs are annually purchased from ten to eleven dealers. For the purpose of making a just comparison as to quality and final cost of fish produced from each purchased lot the eggs received from each dealer are distributed to several hatcheries, that all may be alike subject to different conditions of quality and temperature of the water supply.

At some stations, however, eggs from wild trout are more satisfactory. It has been found that eggs from the domesticated fish hatched and reared in spring water which is not subject to seasonal variations do not produce good results where the temperature of the water supplying the hatchery is below 35° or is subject to variations of several degrees. Vermont and Colorado are the only states in which eggs of the wild brook trout are collected in sufficient numbers to stock the Bureau's hatcheries in those states as well as to have a surplus for distribution to other hatcheries. It is interesting to note, further, that in Colorado, where the eastern brook trout is an introduced species, the eggs can be collected in greater numbers and at less cost than in any other state.

In Vermont[a] eggs are obtained from trout inhabiting artificial lakes on private preserves. During September and October principally, but in some localities beginning sometimes as early as July and continuing into November, the fish ascend the streams in large schools on each rise of water. The fish culturist has only to provide suitable racks and traps in anticipation of the period of migration, constructing them in the streams that have been dammed to make the lakes. The fish are dipped from the trap into adjacent pens above the rack, the pens being kept covered to guard against the escape of the fish in case of a possible flood.

A field station of this character is sometimes managed by one man, who constructs the trap, rack, and pens, cares for and strips the fish, and then cares for the eggs, which are incubated until eyed in stacks of trays in the Williamson type of troughs, then are packed and shipped to the central station at St. Johnsbury.

[a] Titcomb, J. W.: Wild trout spawn; methods of collection and utility. Proceedings of the American Fisheries Society for 1897, p. 73–86.

FIG. 9.—Capturing spawning blackspotted trout in small tributary of Grand Mesa Lake, Colorado.

FIG. 10.—Trap for capturing spawning rainbow trout at mouth of principal tributary to Lake St. Christobal, Colorado.

The construction of the racks under the many varying conditions which are wont to prevail requires good judgment and extreme care. Such barriers must be made in anticipation of and providing for floods and must be fish-tight. One small hole large enough for the entrance of one fish may result in the escape of the entire lot.

The eying stations adjacent to these collecting stations are small inexpensive structures, a shanty 12 by 16 feet being adequate to eye a million eggs.

To compensate for the eggs taken from these waters, about 25 per cent of the fish produced therefrom are returned to them, this being an ample proportion to keep them well stocked. The parent fish are always returned to the waters from which they were captured.

Eggs of the landlocked salmon (*Salmo sebago*) are collected by methods quite similar to those pursued in the brook trout work. Although the range of this species has been extended, the field of egg-collecting operations is almost exclusively the native habitat in Maine.

Perhaps the most extensive trout-culture operations in the world are conducted from the station at Leadville, Colo., in connection with which are field stations for the collection of eggs of wild trout of three species. The output of the Leadville station for 1908 was as follows:

Species.	Eggs.	Fry.	Fingerlings, yearlings, and adults.
Landlocked salmon			8,400
Rainbow trout	45,000	100,000	144,000
Black-spotted trout	1,404,100	3,736,000	210,000
Brook trout	1,833,900	1,905,000	380,500
Grayling		50,000	

SPAWNTAKING IN COLORADO.

To see the methods of work in Colorado it may be well to follow the spawntakers as they leave their camp on one of the Grand Mesa Lakes for a day's work with the native trout of the Rocky Mountains (*Salmo clarki*) at Big Island Lake, 10,000 feet above the sea level.

Each spawntaker is provided with a neck yoke and two 10-quart buckets in which to bring in the results of the day's operations. The fish have assembled in great numbers around the outlet of the lake, where as many as can be conveniently handled are caught at each haul of the seine and the ripe ones immediately stripped. Work at this point may continue all day or it may be advisable after a time to seek other spawning grounds, perhaps at the mouths of small inlets where the water from melting snow is flowing into the lake.

A most interesting phenomenon in connection with this work is the run of trout around the island from which the lake derives its name. Every two or

three years, and possibly more often, at some period during the spawning season there is a procession of fish in twos, threes, and fours around this island. They follow the indentations of the shore line closely. There is no apparent break in the procession, the line being visible from any view point on the shore. It usually continues, moreover, for several days. A 200-foot Baird collecting seine run from the shore line of the island to form an obtuse angle intercepting the run for ten minutes will be full of fish. The spawntakers, standing about the bag of the seine, in two or three feet of water, proceed to strip the fish in the seine while the procession closes in, the line of trout winding in and out about the legs of the men and apparently in as large numbers as before.

The spawntakers with their full pails of spawn proceed to a station near their headquarters, where all eggs are spread on trays and the latter are stacked closely in Williamson troughs supplied with water from an adjacent lake. Here the eggs are eyed preparatory to shipping a portion of them to the Leadville and other stations. Some are hatched at the field station to replenish the waters from which they were collected, or other waters in the vicinity.

REARING METHODS.

At most stations a portion of the fry are reared to fingerlings, and at some stations it has been found advisable to carry brood fish, both of brook trout and rainbow (*Salmo irideus*).

The latter, a native of the streams on the Pacific coast, has been domesticated and successfully propagated at stations in Missouri, Iowa, Virginia, West Virginia, and Tennessee. At stations farther north whose minimum water temperature is usually lower and subject to extreme changes, it has been cultivated with varying, but on the whole rather negative, results. It has been successfully acclimatized in some of the more northerly states, notably in Michigan; but it does not thrive in waters subject to extremely low temperatures during the winter months, and in New York and the New England States has proved in most streams a failure.

The domesticated brood fish of either species are usually the product of eggs collected from wild fish, and are reared in the usual manner. The young fish may be confined for the first four or five months, or until 3 to 5 inches in length, in the hatching troughs or in a battery of outdoor rearing troughs of dimensions and in other respects quite similar to the indoor troughs, about 12 feet long by 14 inches wide. Care must be taken, however, to guard against overcrowding as the alevins increase in growth. The actual number of young fish of a given age which can be successfully carried is dependent upon the quality of the water supply, temperature being an important factor, not only as to the number for a given space, but also as to their rapidity in growth. At the White Sulphur Springs (W. Va.) station, with a supply per trough of 10

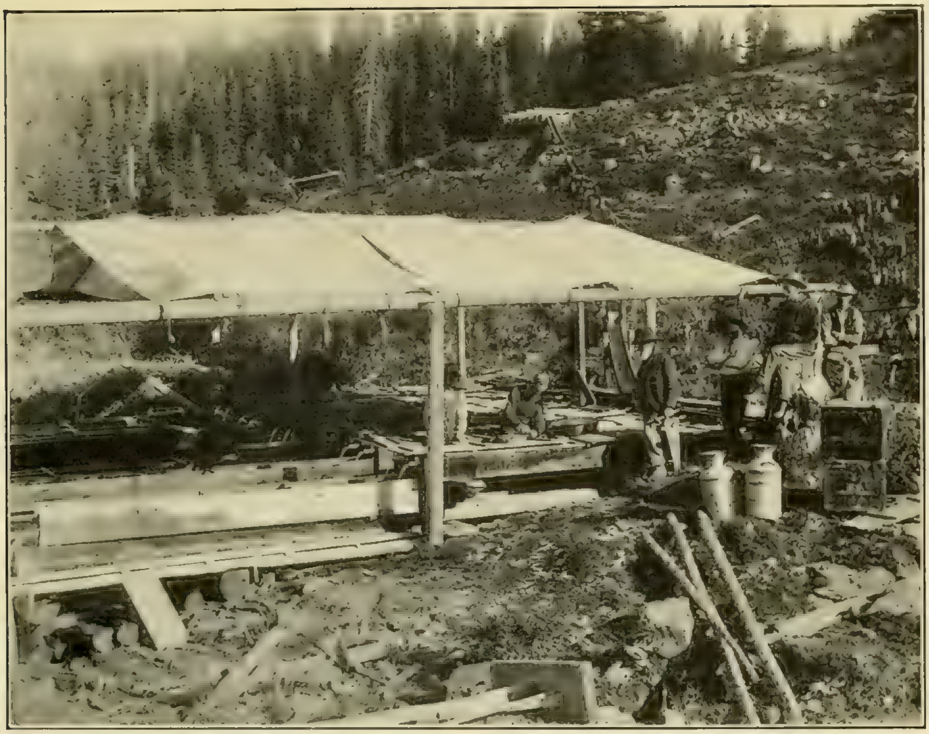

FIG. 11.—Field hatchery at Grand Mesa Lakes, Colorado. Blackspotted trout eggs to the number of 7,000,000 in one season have been developed here to the eyed stage with only a normal loss.

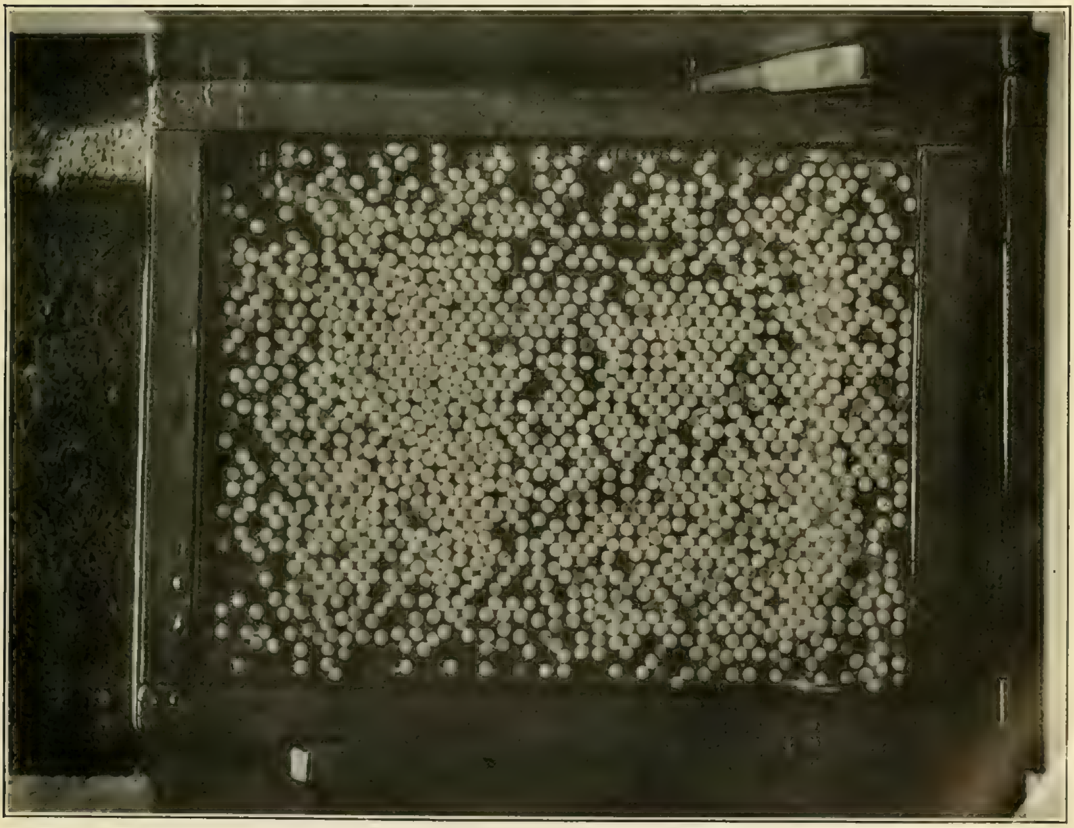

FIG. 12.—Tray of trout eggs in hatching trough. The fry fall or work through the rectangular mesh of the tray bottom into the trough, where they are visible at the left of this picture. Tray is wedged at proper depth in trough during incubation, and, for convenience in removing dead eggs from time to time, may be floated by releasing the wedges.

gallons of water per minute at a temperature of about 50°, it is customary to hatch and hold in each trough 50,000 sac fry, 25,000 advanced fry, 12,500 1¼-inch fingerlings, 4,000 1½-inch fingerlings, 2,000 1¾-inch fingerlings, and 1,000 fish 2 to 3 inches in length. Much larger numbers are often carried under similar conditions without serious loss, though often with the result that the fish prove weak in transportation.

At stations where the facilities permit, a congested condition of the hatching troughs is avoided by transferring some of the fish to outdoor ponds as soon as they have learned to take food readily, or, if weather conditions are suitable, after being fed two or three weeks. In rearing fingerlings for four to six months, concrete ponds 18 to 25 feet in length by 5 to 6 feet in width and 2½ feet deep, with a fall of 8 to 10 inches in the bottom for drainage, give good results at the Manchester (Iowa) station. The stock ponds at Manchester, 76 feet long, 17 feet wide, and 3 feet deep, supplied with 40 gallons of water per minute at a temperature of 50° to 60°, have a capacity for 3,500 rainbow trout 2 years of age; 1,800, 3 years old; 1,000, 4 years old, and 900, 5 years old. This trough and pond system is typical for rearing any species of brook trout, as well as lake trout and Atlantic and landlocked salmons, for three or four months, which is as long as it is customary to hold young fish intended for distribution. Brood fish may be obtained by selection from the fingerlings intended for distribution, which as they develop are transferred to stock ponds.

As soon as the fry swim up looking for food they are fed several times a day an emulsion of finely ground liver. This diet is continued as the young fish develop, with the difference that the liver is less finely ground and is given less frequently—two or three times a day being sufficient when the fish have attained a length of 2 or 3 inches. The kind of liver used varies at different stations, that of sheep, beeves, and hogs being extensively used, and the relative value of each being in the order named. The food for the larger fish consists of the liver, lungs, and hearts of the animals already mentioned.

At Manchester, Iowa, it has been found advantageous from an economical standpoint to mix the animal food, after it has been ground, with a mush made by cooking wheat middlings or shorts, to which a moderate amount of salt is usually added. After the mush has been thoroughly cooled the animal matter, uncooked, is stirred into it in the following proportions: For fingerlings, 1 part animal matter and 2 parts mush; for adults, 1 part animal matter and 3 parts mush. Twenty gallons of boiling water and 50 pounds of wheat middlings will make about 202 pounds of mush.

The provision of food for domesticated fish is one of the greatest problems the fish culturist encounters, and has been the subject of considerable experimentation. The intensive production of natural food has not received in the United States so much attention as in Europe nor so much as the subject

deserves. The American method of raising trout precludes the economic use of natural live food, although unquestionably the edible qualities of the fish might be much improved thereby.

For several years the roe of the branch herring (*Pomolobus pseudoharengus*) has been used at several stations as a substitute for liver in feeding fry and fingerlings. It is purchased from cannery men, who preserve in tins large quantities of it for human consumption, and consequently are able to sell it at a price close to or less than the cost of liver, due allowance being made for the waste in liver and the labor involved in its preparation as a fish food. The herring roe has the advantage of always being on hand in condition ready to feed and is therefore especially desirable for isolated stations. It is not customary to feed young fishes on this food after they are 2 or 3 months old.

At Craig Brook, Me., fly larvæ,[a] used for a number of years in rearing trout and salmon to fingerlings, proved to be a very satisfactory food and the fish attained a more rapid growth than when fed on liver and other dead material. From a financial standpoint it was not as economical as freshly prepared liver or other animal foods, and this, coupled with the objectionable odor attendant on its preparation, had much to do with its discontinuance.

It is possible, however, to utilize animal refuse advantageously for the production of fly larvæ by means of a contrivance in which the material on which flies have deposited their eggs may be suspended over the water. This contrivance consists of a wooden frame, like a box without top or bottom, placed on floats and having an air-tight cover to prevent the escape of foul odors. Within the frame are two trays, the bottoms of which are made of coarse wire cloth (odds and ends of old hatching trays). Excelsior or straw is placed on the trays, and waste meat or other animal refuse is placed on top of this material. As the larvæ hatch they work through the excelsior, cleaning themselves thereby, and drop into the water. Two small trays are preferable to one of larger size, that the meat may alternately be renewed, thus insuring a more constant supply of larvæ. The noxious animals killed in the protection of fish may advantageously be disposed of in these trays.

SPECIAL DEVICES APPLIED AT TROUT STATIONS.

Study and experience in recent years have revealed abnormal aeration as a condition existing in various water supplies at trout-culture stations, with consequent mortality among the fish. Of the methods used to correct such abnormalities, that devised by the superintendent of the station at White Sulphur Springs, W. Va., Mr. R. K. Robinson, has proved the most efficient.

[a] Atkins, Chas. G.: The live food problem, American Fisheries Society, 1903; also Food for young salmonoids, Proceedings Fourth International Fishery Congress, Bulletin Bureau of Fisheries, vol. xxviii, 1908, p. 839–851.

It consists of a series of ordinary milk pans held in a frame, one above another, in numbers to suit conditions, the bottoms of the pans perforated with a nail or other pointed instrument which will leave a ragged edge to each perforation on the underside of the pan.

This apparatus is set up at the head of the trough in such position that the supply pipe empties into the topmost pan, and the water must pass through the series before reaching the trough. By this separation into fine streams the water is thoroughly exposed to the air, thus rectifying any abnormality of air content.

At nearly all trout hatcheries it has been customary to place horizontally below the supply pipe at the head of each trough a screen consisting of a light frame, bottomed with wire cloth or perforated metal. This is designed not only to break the force of the stream entering the trough but to aerate or deaerate the water and at the same time catch foreign substances and animal life—the latter at times being quite objectionable. Such screens, however, have almost invariably caused the water to spatter over the sides of the trough, resulting in constantly wet surroundings. To overcome this objectionable feature a conical perforated screen has been devised by Mr. M. E. Merrill, of the St. Johnsbury, Vt., station. When the screen is in place the current of water falls directly on the apex of the cone, and thus is spread over the entire perforated surface, accomplishing the objects of all other styles of head screens, and avoiding the spattering of water over the sides.

A device for assorting young salmon and trout was introduced in the Bureau's operations by Mr. J. P. Snyder, an employee at one of the stations. It consists of a series of screens by means of which to separate the fingerlings into sizes.

In length the screens are slightly less than the width of the troughs, to facilitate sliding them along. There should be two screens for each size of mesh. In use one screen is carefully inserted at the foot of the trough close to the tail screen, due precaution being taken that no fish are pinched and that none are left between the foot screens and the end of the trough; midway of the trough a screen should be securely fastened in a vertical position by wedging. After the first screen is in position a similar one is inserted at the head of the trough and then moved along toward the center.

As the two screens are brought closer together the fish between them become frightened, and all that are small enough escape through the mesh of the screens. The distance of the second screen from the first should depend upon the number and size of the fish in the troughs, and also upon the number that escape through the screen. The second screen should also be fastened by wedging. Then the hand of the attendant is moved about among the fish between the screens to guard against any small ones finding a hiding place. In

their efforts to escape some of the fish will be hung in the wire cloth, but it will be noticed that every trout which gets its head through the screen can pass or be assisted through without injury. The few which are caught in the mesh should be assisted by grasping the tail and pushing them. It would be well to refrain from feeding for about twenty-four hours before assorting the fish.

By using two or three sets of screens in different troughs at the same time one man can assort many thousands of fish in a day, and the sizes will be much more uniform than when assorted with a scaff net. Wire cloth, 6 bars to the inch each way, painted with asphaltum varnish, will permit all brook trout under 1 inch in length to pass through. By varying the mesh of screens brook trout may be assorted into six uniform sizes as follows:

Number of bars to the inch:	Size of fish.
6	All under 1 inch.
5	All between 1 inch and 1½ inches.
4	All between 1½ and 2 inches.
3	All between 2 and 2⅜ inches.
2$\frac{5}{16}$	All between 2⅜ and 3 inches.
2	All between 3 and 3⅞ inches.

The frames of these screens are made of half-inch wooden strips grooved and tongued at the ends. These frames are one-eighth inch less in length than the inside width of the troughs and in height equal the depth of the troughs, being rectangular in form. They are covered on one side with wire cloth held firmly by copper tacks, both the wire cloth and the frames being painted with asphaltum varnish previous to tacking the wire on the frames. This not only helps to preserve the wood and keep the wire from rusting, but smooths the latter so that there are no rough surfaces or projections to injure the fish as they work their way through.

ATLANTIC SALMON.

Another important branch of fish culture is conducted at the Craig Brook station, near the Penobscot River, not far from Bucksport, Me. While not restricted in its work to this one species of fish, the primary object of this hatchery is the propagation of the Atlantic salmon. The decadence of this important fishery on the North Atlantic coast, due to the ruthless but natural progress of civilization, is too well understood to call for an explanation here. Suffice it to say that to-day the Bureau is maintaining a commercial fishery for the Atlantic salmon on the Penobscot River purely by artificial propagation. It is the only river in the United States where this once abundant salmon is now found in sufficient numbers to support a fishery or to warrant its artificial culture, and here, with the natural conditions so changed, it is with no little difficulty that the extinction of the species is prevented.

FIG. 13.—Series of covered trout-hatching troughs at White Sulphur Springs station (West Virginia) equipped with the Robinson pan aerator. (See p. 716.)

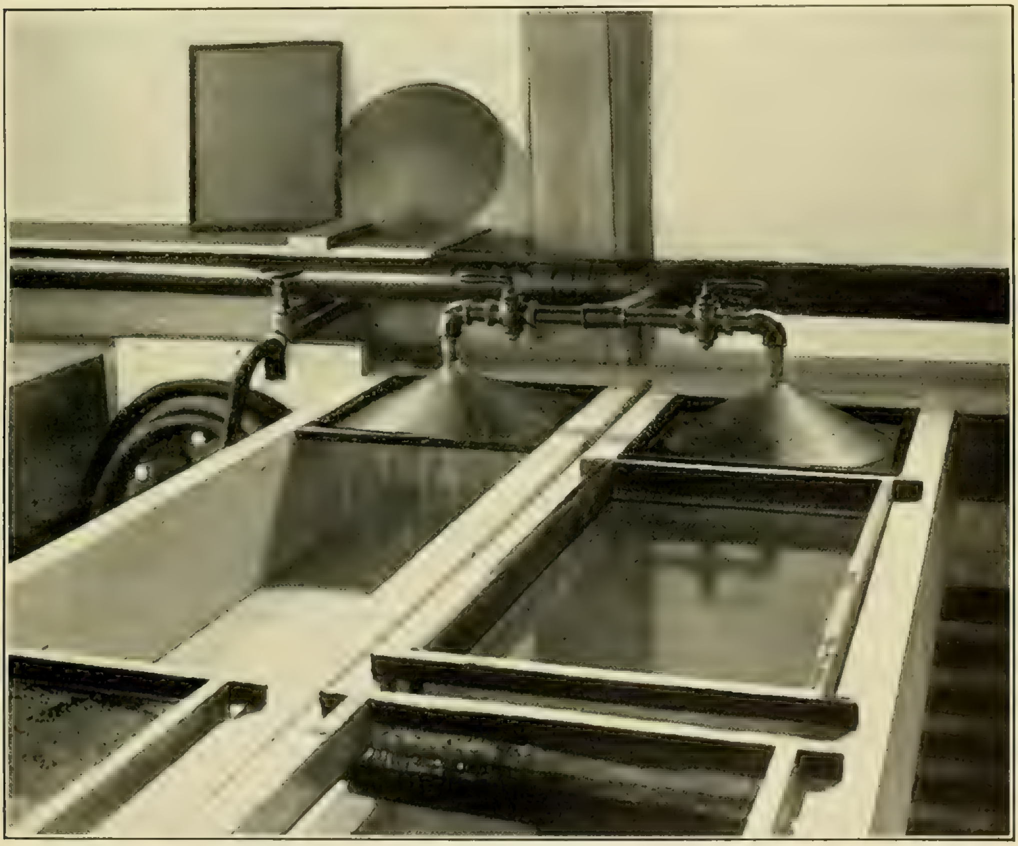

FIG. 14.—Trout-hatching troughs with Merrill aerating cone. (See p. 717.) Shows also tray basket of a pattern used at some trout stations, much deeper than ordinary tray and intended to hold fry after hatching. Left trough with tray removed to show shower of water produced by aerating cone.

The operations at this hatchery, fully described in the Manual of Fish Culture published by the Bureau of Fisheries in 1900, have undergone slight change of method and need not be dwelt upon here. The source of egg supply is the catch of the fishermen's weirs usually during the month of June, the fish being purchased and towed in live cars to the station, where they are transferred to inclosures and there retained until the spawning season, in October and November. When ripe they are stripped and the eggs placed upon wire trays, which are stacked in troughs and carefully tended until the early spring, when the eggs hatch. The young fish are distributed for the most part as fry, but a considerable number are reared to the fingerling stage.

POND CULTURE.

Pond culture in the United States is applied only to nest-building fishes, such as the basses, sunfishes, and the common catfish (*Ameiurus nebulosus*). These species do not submit to manipulation for taking and fertilizing their eggs, but fortunately a very large percentage of the eggs are fertilized when the spawning functions are permitted to occur naturally, and the parent fish care for and protect the young until the latter are free swimmers. The cultivation of these fishes, therefore, consists in providing ponds which shall give to the maximum number of breeding fish and their young all the essential conditions of a natural environment, while at the same time protecting them from their enemies and holding them under control.

THE PONDS.

Economy in construction usually dictates the shape and area of the ponds, but an independent water supply and drainage to each is desirable. For convenience of the fish culturist the area usually ranges from one-fourth to one acre, although some ponds of larger size are desirable. It was formerly considered essential to have at least one-fourth the area of the breeding pond not exceeding 1 foot in depth, but it has been found that the deepening of the shallower portions to a minimum depth of from 1 foot to 1½ feet has largely increased the productive area.

The presence of aquatic plants in fish ponds is a prime essential. The young of the nest-building fishes do not accept artificial food, and must therefore have their natural diet of minute animal life, the abundance of which is dependent to a large extent upon the character and abundance of plant growth. Plants are also important as oxygenators of the water and afford shelter and shade for the fish. The selection and control of aquatic vegetation, therefore, is a matter to which the fish culturist must give much attention, and experience at the various stations indicates that it offers a direct means by which the output

of the ponds may be increased. The subject has not been sufficiently studied, but observations so far made suggest various practical possibilities of much interest.[a]

The supposed loss of young fish by the voracity of their parents induced the practice of partitioning the ponds in such a manner as to confine the adults in one portion while permitting the young to escape through the partitions to safety. It has been found, however, that the loss from cannibalism is due chiefly to the young fish themselves, and accordingly they are separated from their parents or not, merely as a matter of convenience. The principal precaution against cannibalism is, instead, the provision of an abundant food supply, to divert the fish from each other.

FOOD FOR THE ADULT FISHES.

Food for the adult fishes is largely a matter of local conditions and convenience. Chopped fish is extensively used at some stations, and crawfish, so abundant in some localities, when chopped make admirable food for the adult stock. The basses, although not appearing to care for pollywogs as naturally present in the ponds, will devour frog tadpoles voraciously if the latter are seined out and thrown back by the fish culturist, but they absolutely refuse toad pollywogs when similarly served to them. Minnows are a good food, but should not be introduced into the ponds near the spawning season, as they eat not only the small forms of life upon which the fry depend but often eat the fry as well. Dead minnows thrown into the water one at a time are greedily taken by the adult basses.

Adult bass may also be advantageously fed on strips of beef liver about 2 to 3 inches long and from one-half to one-fourth inch in width or thickness; and prepared food consisting of ground liver or other animal substance mixed with a mush of cooked shorts, corn meal, or middlings has been employed in a rather limited way. It is worthy of note that for this prepared food to be attractive to bass it must ordinarily contain at least two-thirds of the animal substance, whereas prepared food containing only 10 per cent of the animal material is taken with avidity by trout.

It has been quite conclusively demonstrated that one of the principal causes of loss among brood fish is overfeeding, resulting in a fatty degeneration. This loss has been largely overcome by reducing the food supply and at the same time varying the kind of food furnished.

ARTIFICIAL NESTS.

In the cultivation of the small-mouth bass, and to some extent the other species, it has been found profitable to provide artificial nests. These are of

[a] Titcomb, J. W.: Aquatic plants in pond culture. Bureau of Fisheries Document 643. 1909.

FIG. 15.—Placing cheese-cloth retainers over nests containing bass fry about ready to swim up. Most of the nests are seen covered with retainers. When a nest is occupied it is numbered and complete record kept of its different stages. The retainers are to confine the fry for convenience in transferring to other ponds to make room for following broods. (Mammoth Spring station, Arkansas.)

FIG. 16.—Pond drawn down and nest boxes placed for spawning. Area of pond, 55,000 square feet; 50 nests in pond; 150 breeding smallmouth black bass. (Mammoth Spring station, Arkansas.)

various design, but embody in general some sort of a container for the gravel the fish require, together with a shield or screen on two or three sides.[a] The primary use of screens was for the purpose of shielding the fish from view of passers-by, but the practice resulted in the discovery that the fish will accept shielded nests at more frequent intervals than when visible to each other. It is therefore of first importance that in the placing of nests the screens be arranged to meet this condition.

When shielded artificial nests are not provided it is customary to deposit here and there in the ponds mounds of coarse gravel, 18 inches to 2 feet in diameter and about 6 inches in height, that the breeders may select and prepare their nests with these.

Large-mouth black bass, though they sometimes accept gravel mounds as nests, naturally seek a weedy bottom, devoid of gravel. Peat-like sods or similar substances put into the pond prove acceptable to this species as nesting material.

The superintendent of the Cold Springs, Ga., station endeavors to imitate nature by providing "homes" for all adult fishes whether spawning or not. For the large-mouth black bass and rock bass, boards 3 feet to 10 feet in length are laid flat under the water so that by the natural contour of the bottom spaces 5 inches to 8 inches deep are formed under the boards. Catfish (*Ameiurus nebulosus*), which prefer to dig their own nests, are provided with boards either laid flat on the pond bottom or where there will be under the center of the board a depression an inch or two in depth. Where necessary, the boards are fastened by stakes at both ends, but when placed along the bank, where conditions are favorable for such a course, one end of the board may be driven a short distance into the embankment, while the other end is staked. After having been submerged a month or so the boards will remain in place without fastening. With proper precautions against projections these shelters do not materially interfere with seining operations.

For the crappie, roily water seems to be essential during the spawning season. At stations where there are no naturally roily ponds it has sometimes been found desirable to introduce a few carp, which roil the water in rooting around the bottom of the pond and do not seem to disturb the crappie.

NUMBER OF BROOD FISH.

The desirability of maintaining a maximum number of brood fish to a given pond area has led to a comparison of experience at the different stations in an effort to arrive at some approximate average for a working basis. Conclusive

[a] One form of nest in use is the design of A. E. Fuller, described in his paper entitled "New and improved devices for fish culturists," Proceedings Fourth International Fishery Congress, Bulletin U. S. Bureau of Fisheries, vol. xxviii, 1908, p. 991–1000, pl. CIV–CVI.

determination can not be made, of course, owing to the various factors of quality and temperature of water, abundance of vegetation and of natural food, etc., but reports from the several localities are of interest.

At San Marcos, Tex., the best results are obtained with 24 to 30 large-mouth bass to the half acre; of the smaller fishes—bream, rock bass, crappie—60 to the half acre.

A 1-acre pond at Mammoth Spring, Ark., supports 100 small-mouth black bass, and an average of 2,000 fry to each productive nest has been obtained, the maximum number from one nest being 5,200.

At Cold Springs, Ga., 100 adult large-mouth black bass in a pond of three-fifths of an acre in area proved too many, and the number had to be reduced to 60 or 70 for satisfactory results. In general, 50 to 75 brood bass to three-fourths of an acre to an acre have been found the best number at this station. Of catfish (*Ameiurus nebulosus marmoratus*), 100 to the acre have been found satisfactory.

Ponds at Wytheville, Va., accommodate 75 pairs of large-mouth black bass to the acre with good results; of rock bass, 300 fish to the acre.

At Northville, Mich., in a pond three-fifths of an acre in area it has been observed that most satisfactory results were obtained with small-mouth bass to the number of 29 females and 23 males, allowance being made for the occasional polygamous tendency of the male.

At White Sulphur Springs, W. Va., 36 pairs of small-mouth black bass is considered the number for a 1-acre pond.

The maintenance of an abnormally large number of brood fish to a given area results in more or less loss according to species, the mortality among the brood fish of the small-mouth black bass being greater than with the large-mouth bass and other pond fishes. The replenishing of the stock is most advantageously accomplished by securing wild fish, preferably in the spring of the year, and they may be advantageously transferred up to within two or three weeks of the spawning season.

COLLECTING THE YOUNG FISH.

It is often desirable to remove the surplus fry from a pond before they have left their nests, and there is now in use for this purpose a combination fry trap and retainer which is placed over the nests, taking advantage of the fact that the fry rise vertically.[a] This trap has proved of practical value in fish-cultural ponds for small-mouth bass, and, where the nest area was not too great, for large-mouth also. It has been used likewise in collecting small-mouth bass fry from natural lakes, and is believed to be applicable to fry of other nest-building fishes than the basses.

[a] See Fuller, op. cit.

Soon after the yolk sac has been absorbed, or after the fry have been feeding for two or three weeks, a portion of them are removed from the ponds and distributed to the waters they are to stock. The first crop may often be obtained by seining around the edges of the pond without the preliminary clearing away of vegetation, and for this purpose a novel casting seine has come into use at Northville, Mich. The web is rigged upon two long bamboo poles, so that the device may be operated entirely from shore, without roiling the water or unduly disturbing the fish.[a]

After the young fish have sought the deeper portions of the ponds, preliminary to drawing off the water to effect their capture, it is necessary to remove the aquatic vegetation, a process of much labor and expense, consisting in general of mowing under water, and carrying away the foliage by means of pitchforks and boats. Various methods and devices for this purpose have been evolved at the different stations, as described elsewhere.[b]

Ordinarily the assorting of young pond fishes by size is accomplished by hand manipulation with a scaff net. To some extent, however, the separation may be accomplished by regulating the size of the mesh in the nets used to effect their capture. The superintendent of the San Marcos, Tex., station suggests having an ample bag to the dip net in which quite a large lot of fish may be taken from the tub or other retainer, then passing the net gently to and fro in the water to allow the fry and smaller fish to escape, while the larger ones are retained. This method is principally used for assorting black bass, as it frequently happens there are schools of both fry and fingerlings in the ponds at the same time. Nets of one-fourth inch square mesh will permit the escape of all fish up to 1½ inches; one-half inch square mesh will permit the escape of all fish under 3 inches in length.

At the Cold Springs, Ga., station the superintendent uses a box 3 or 4 feet long by 1 foot wide and 1 foot deep, and water-tight to a depth of 2 inches. Above this 2 inches one side is covered with wire cloth instead of being closed in, the size of wire mesh being regulated for known sizes of fish. The box is partially submerged in the pond in which it is intended to place the smaller fish of a lot to be assorted. The young fish as caught are placed in the box, and then are left undisturbed for an hour or two. At the end of this time the smaller fish will have escaped from the box through the screen into the pond, when the box with the larger fish remaining in it may be transferred to another pond and emptied, or the contents may be poured into a suitable receptacle for transportation by tipping the box toward its solid side. Square-meshed galvanized cloth is used for the screen, and if the fish are given plenty of time to separate none of them are gilled, hung, or otherwise injured.

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[a] Fuller, op. cit.

[b] Titcomb, J. W.: Aquatic plants in pond culture, Bureau of Fisheries Document 643. 1909.

RESCUE OF FISHES FROM OVERFLOWED LANDS.

In the upper Mississippi and Illinois rivers there is an annual spring flood period caused by the melting of the snow in the northern forests and freshets in the local tributaries after heavy rains. The period begins with the approach of warm weather, usually about March 15, and continues until about June 1, when the crest of the high water has been reached. Soon after this date the water begins slowly to recede, and usually by July 15 the river has reached its normal stage.

Between the extreme low and high water marks there is a variation of 12 or 15 feet. There is, of course, a variation in the extremes of the water level in different seasons, but seldom, if ever, does the water fail to rise high enough to flood the lowlands. The adult fishes are thus permitted to enter the overflow basins and bayous, and invariably do so during the spawning season. After spawning most of the adult fish escape to the river before the water has receded sufficiently to cause them to be hemmed in, but immense numbers of their progeny are left in the lakes and bayous where they were hatched. These waters gradually dry up, become choked with vegetation, or overheated and unfit for fish life; some of the larger and deeper lakes and bayous, although cut off from the main river, may contain water the year around, but on account of the seepage and evaporation during the summer the depth of water in them decreases to such an extent that they freeze solid during the winter months. Sometimes the lakes from which fishes are rescued are in the hollows on farm lands, where in dry seasons crops are cultivated. Thus it will be seen that the fish imprisoned in overflow waters are doomed to destruction in one way or another.

One branch of the Bureau's operations is annually to rescue large numbers of these fishes. At present the work is confined to waters convenient of access—namely, the overflow lakes and bayous on the low islands in the rivers and on the adjacent mainland. Many of the fishes are returned to the rivers. Another portion of the more desirable species is distributed in various other waters, often far from the source of supply.

It has been found, however, that the fishes rescued from these warm waters do not bear transportation long distances without heavy losses if immediately started upon their journey. Therefore a hardening process is resorted to, which consists in holding the fish in large tanks flowing through which are streams of clear cool water. To facilitate the work the Bureau has a number of field stations—one on the Illinois River and three on the Mississippi—convenient of access to the railroad, and each equipped for holding one or more carloads of fishes for several days, or until they have become sufficiently hardened to bear transportation by cars. Adjunct to these stations are vessels, launches, and boats of various types suited to the work.

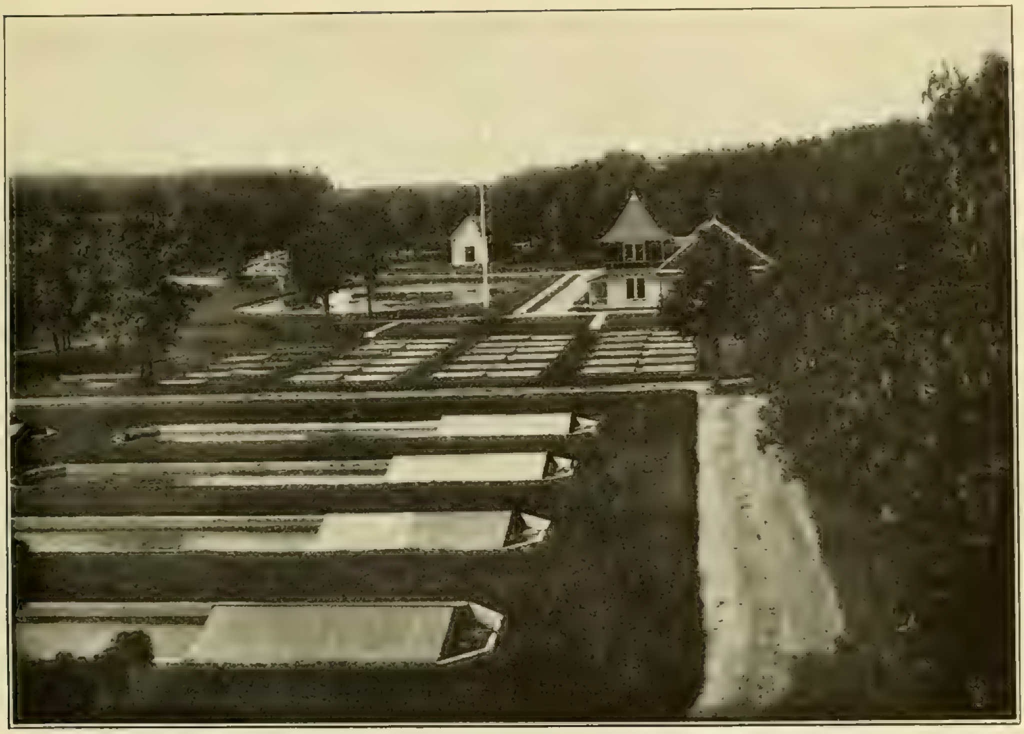

FIG. 17.—Both trout and bass are cultivated at many of the stations. This view of the station at Manchester, Iowa, shows stock ponds in foreground, then the smaller nursery ponds, all of these for trout and built of cement. Beyond, in front of the hatchery building, is a bass pond, with earth bottom and sides.

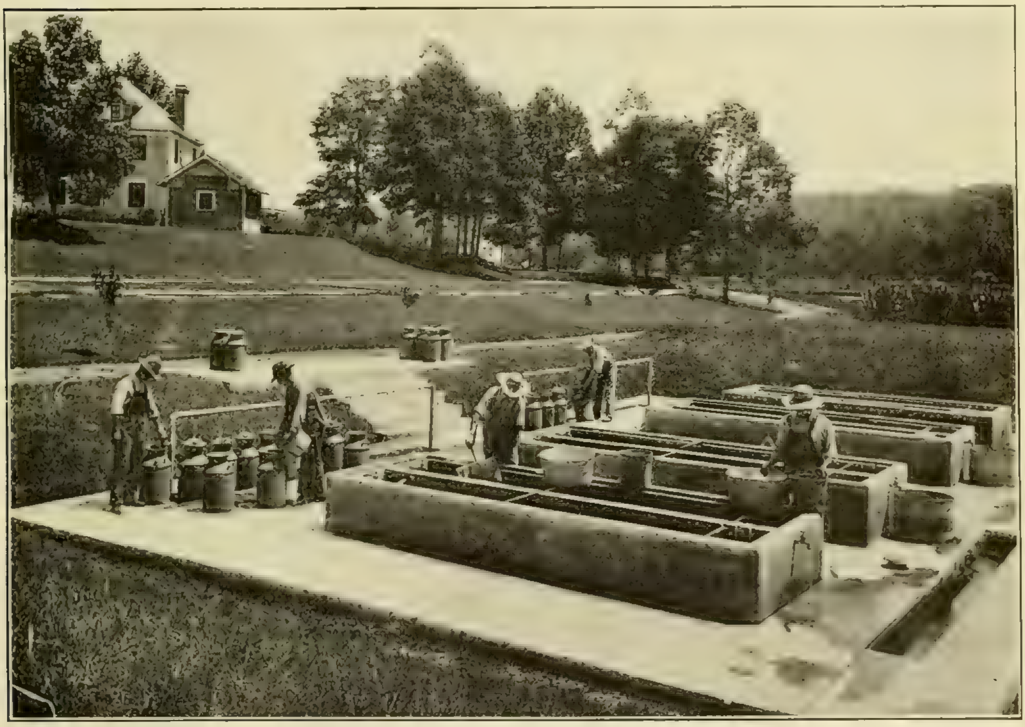

FIG. 18.—Preparing a shipment of smallmouth bass. Tanks used for hardening the young fish prior to transportation. The fingerlings are held for 12 hours in cold spring water, then dipped into tubs, counted into pails, and transferred to the transportation cans. These are then placed under a $\frac{3}{16}$-inch stream of spring water and held until train time. For an early morning shipment the fish are "canned" the evening before. (Mammoth Spring station, Arkansas.)

By this means not only is a conservation effected but the Bureau is enabled to meet the great demand of applicants for the basses, sunfishes, and perches at a less sum than it would cost to produce them at a station maintained especially for their propagation.

THE PACIFIC SALMONS.

On the Pacific coast the Bureau has six permanent stations, including two in Alaska, all of them maintained primarily for the propagation of the Pacific salmons. Subsidiary to these there are six important field stations and other smaller ones where salmon eggs are collected and hatched. An idea of the extent of the work may be obtained from a statement of the output of these stations during the fiscal year 1908.

Output of the Pacific Salmons in 1908.

Stations.	Species.	Eggs.	Fry and fingerlings.
Alaska	Sockeye		61,369,000
California	Chinook	64,990,550	4,780,855
Oregon	Chinook	[illegible]	[illegible]
	Silver		[illegible]
Washington	Chinook		498,309
	Silver	296,000	13,262,714
	Sockeye	75,000	8,514,305
	Humpback	502,000	6,764,762

The eggs shown in this table were transferred to state fish hatcheries and other places for incubation. In California, as will be noted, a very large proportion of the eggs taken are so distributed.

Observations at various field stations indicate that a large percentage of salmon eggs deposited naturally are fertilized but for various reasons only a small percentage hatch. Modern fish-culture methods permit of a much higher percentage of impregnation than under natural conditions, it being possible to actually hatch and distribute as fry more than 95 per cent of all eggs collected. So long, therefore, as a proper number of salmon are permitted to escape the various fishing devices in their ascent to the natural spawning grounds, and it is possible to capture them for the purpose of obtaining and impregnating their eggs, perpetuation of the salmon fishery is assured.

In the culture of the Pacific salmon it is impossible to save eggs from the commercial catch, because the latter is made before the fish are ripe, and to retain them until ripe is not feasible. By the time they have ascended the rivers to the spawning grounds and are in condition for the fish culturist the flesh has so deteriorated in quality that they are unfit for market in any form. The Bureau must therefore itself capture the fish it requires, and this is usually done by the construction of barricades to intercept the run at the most suitable point below the spawning grounds.

BARRICADES AND TRAPS TO INTERCEPT SPAWNING RUNS.

That successful work at the salmon stations depends largely upon stable and suitable barricades, or racks, as they are more commonly called, may be instanced by the results of the work at Battle Creek, Cal., in 1903 and 1904. At the height of the season in 1903 a freshet carried away several sections of the rack grating, permitting the fish to escape upstream.[a] As a consequence only about 27,000,000 eggs were secured. The following season no flood occurred at Battle Creek until near the end of the spawning season, and the collections that year numbered over 57,000,000 eggs.

As all of the streams are subject to freshets, the water in some instances rising over 20 feet, the racks must be firmly built, and their successful operation depends not only upon ingenuity in construction but the care that is taken to guard against their becoming clogged with leaves and other débris in times of flood—work which at times is exceedingly hazardous. Methods in the construction of racks vary with local conditions, as do also the methods of capturing the salmon thus intercepted.

At the Mill Creek station, in lieu of a main or upper rack, the Bureau is able to take advantage of a mill dam 12 feet high, which effectively stops the passage of salmon. Half a mile below this dam a retaining rack with the usual traps prevents the fish from dropping down stream. Seining and spawning operations are conducted on the streams between the dam and the retaining rack.

At Baird, Cal.—At the Baird station on the McCloud River in California are two racks or barriers between which is formed a pool 400 feet in length. The upper rack intercepts the further passage of salmon, and the lower or retaining rack gives the fish free entrance to the pool, but effectually prevents their return. The upper rack reaches across the river, a distance of 250 feet, and is primarily supported by 10 concrete piers averaging 8 feet in height and extending 5 feet above low-water mark. The piers are properly fastened to the bed rock of the river bottom by means of heavy iron bolts. They have a flat top 4 feet wide and 6 feet long, and from top to bottom is a beveled nose extending upstream at an angle of 60 degrees, making them 4 feet wide and 10 feet long at the bottom. On either bank a small crib pier filled with rock supports the shore ends of two 10 by 10 inch stringers laid parallel from shore to shore across the tops of the piers. A 2-foot walk is built between the stringers and the whole is securely wired to eyebolts built in the pier tops.

Across the river bottom, against the nose of the piers, is a 10-inch sill. At intervals of 3 feet poles 4 inches in diameter extend at an angle of 60° from the sill at the bottom to the stringer at the top, and are securely fastened to the

[a] At Battle Creek the low-water mark is 10 feet below the top of the stringers on the rack, and during a recent flood the water was 12 feet above the top, making a 22-foot rise.

latter by large spikes. Against these poles or inclined uprights rest the gratings of the rack, which for the sake of convenience in handling are built in sections 6 feet wide and from 6 to 10 feet long to suit the varying depth of water. The gratings are made of 1½ by 3½ inch slats of dressed lumber set 1½ inches apart, their thin edge facing the current, the edge being convex to facilitate cleaning, and permit the passage of leaves. The ends of the gratings are nailed between two pieces of 1½ by 4 inch material, notched into the slats to make a flush surface. The space between the slats is gaged by nailing on 1½ by 4 inch blocks to each end. The longer gratings are braced with two strips 1½ by 4 inches nailed on 3 feet from the bottom.

In the upper rack is placed a trap 10 feet square with vertical slat sides similar to the rack gratings and having a solid board bottom. The narrow opening which allows the fish to enter is so constructed as to reduce to a minimum their chance of escape. The trap is primarily used for observing the general condition of the fish in the pool prior to the beginning of seining or spawning operations.

The retaining rack is at the lower end of the pool, where the stream narrows to about 190 feet. It is supported on 6 stone-ballasted crib piers with sides 14 feet long, made by spiking together logs 8 to 12 inches in diameter until the required height is reached. The piers are built on shore, floated into place, and filled with rock. Across the upstream end of each pier are two 10 by 10 inch stringers laid parallel and supporting a board walk, as in the upper rack. Two small temporary piers are also built, to support the shore ends of the rack. Gratings having 2-inch interstices are placed across the stream, similar to those in the upper rack, with the exception that 5 openings 2 feet wide are left between the piers nearest the center of the stream. These openings are covered by the usual traps, which extend upstream into the pool 9½ feet. The traps are 4 feet in height and 6 feet in width at the entrance, being shaped to fit the slant of the gratings. The sides are of 1¼ by 4 inch material spaced 2 inches apart, and with the broad edge toward the current. Braces are placed across the top, and at the apex of the trap is an opening 3 inches in width from the surface of the water to the bottom. The salmon pass into the pool through this opening and rarely, if ever, find their way out.

Before the installation of the retaining rack, some ten years ago, many eggs could not be collected by reason of the loss of fish from their running back downstream. This violation of the natural instinct of salmon to work ever upstream was due to fright resulting from the continual sweeping of the seine just below the upper rack. In the early days Indians were engaged to walk on either shore for a mile or so below the rack and beat the water with brush in an endeavor to drive the fish up to the seining ground. Since the installation of the retaining rack such measures have been entirely unnecessary.

At Battle Creek, Cal.—The main or upper rack at Battle Creek, Cal., is constructed on a comparatively soft and shifty river bottom, and is supported by piling, instead of by the log cribs anchored with rocks, more generally used. There are 12 bents of piling, each bent consisting of 3 piles driven firmly and braced with heavy timbers. The 3 piles comprising a bent are driven parallel with the current, the front one standing some 2 feet above low-water mark and the others about 8 feet above. The front and rear piles are placed about 10 feet apart. On these bents of piling and reaching across the stream are placed three 12 by 12 inch stringers, against which are secured 4 by 4 inch slanting supports, about 6 feet apart, the lower ends of which rest on a mud sill placed in the bottom of the stream. Stringers and these supports are so placed that the face of the rack will meet the current of the stream at an angle of about 60°. The gratings of the rack are built in sections of varying length but of a uniform width of 5½ feet. The slats for these gratings are of dressed lumber 1 by 3 inches, the sides set parallel with the current, the upstream edge convex. At either side of the stream, in the shallower water, single sections of gratings about 10 feet long extend from the bottom to the top stringer. In the deeper portions of the stream two 6 or 8 foot sections of the gratings are used, one above the other, with an opening between the upper and lower sections for convenience during the lower stages of water in the removal, with rakes and hooks, of rubbish and trash drifting downstream. When the water rises the closing of this aperture is easily accomplished by knocking out the blocking between the two, thus permitting the upper rack to slide down flush with the upper edge of the lower section. The length of the rack from shore to shore is about 300 feet, its vertical height above low-water mark being about 8 feet. During low water the front is submerged to a depth of from 18 inches to 2 feet, but there are holes considerably deeper behind the rack. A walk 2 feet wide is built on the top of the rack. A half mile below the barrier is a retaining rack quite similar to the one described for the Baird station.

At Battle Creek the racks are usually installed during September in time to intercept the fall run of salmon, and unless carried out by high water, remain until the close of the work in December. Gratings, stringers, etc., are then removed and stored for use another season.

At Birdsview, Wash.—A permanent barrier at the Birdsview station, an auxiliary of the Baker Lake station, in Washington, is of novel construction and calls for more than passing notice. This barrier is located in a portion of Phinney Creek where formerly there was a dam built for the purpose of obstructing the passage of steel-head trout. When the dam washed out, a new channel formed and the river bed was very much broadened.

The first step in the construction of the new barrier was the laying of four heavy log stringers across this new channel from the abutment on the north to

FIG. 19.—Main rack across Battle Creek near the Battle Creek station, California. Upper sections of rack raised to facilitate disposal of leaves and other débris.

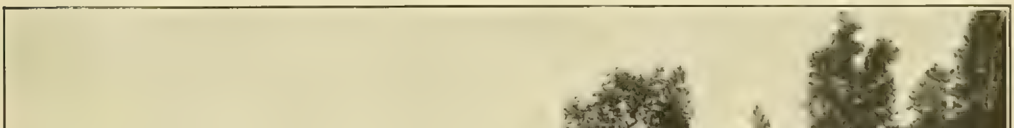

FIG. 20.—Seining spawning salmon on the McCloud River, California, at the Baird station. Steam power has now replaced the hand windlass.

the new bank on the south side of the stream. The logs were let down through the dam foundation to low-water level on the north side and the deep channel under them on the south side was filled with brush and gravel. The logs were spotted down to form a practically level bed, reaching the width of the stream. Heavy piles were then driven behind each stringer to form alternate single and double rows extending up and down stream. The log stringers were next planked over, forming a platform 18 feet wide, similar to a regular dam apron, extending from the north abutment to the final row of piles on the south side, a distance of about 140 feet.

By planking the sides of the single rows of piles and all around the double rows and filling the space with rocks, piers 4 feet high and approximately 2 feet and 4 feet wide were formed. Through each pier at the bottom, behind the upstream pile, openings 1 foot square were left, connecting the spaces between the piers. These spaces, 12 in number, are approximately 8 feet wide and are filled by swinging gates hinged to a 3 by 12 inch timber, spiked securely to the piers on either side and forming a dam or flashboard across the space above. By the insertion of other flashboards above this one a tight dam 4 feet high can be quickly formed at any time. The utility of this feature will be explained elsewhere.

The gates are made of 1 by 4 inch fir set on edge and nailed to 2 by 4 inch joist, being strengthened by 2-inch blocks set between the rack bars and nailed to them and the joists. These blocks thus determine the width of the interstices in the gates. At the upper end of each gate an auger hole is bored through the bars and blocks, to accommodate a 2-inch iron pipe, which passes through the entire upper end of the gates. Ringbolts clasp these pipes and are fastened to the 3 by 12 inch timber forming the flashboard, acting as hinges upon which the gates swing. At the lower end of each gate a wide board, 1¼ by 16 inches, is secured by means of braces, forming an angle of 45° with the lower end of the gate.

At any ordinary stage of the stream the downstream ends of the gates rest on supports which hold them a foot or more higher than the upper ends, the water passing down through them to the floor of the apron, where it runs away. The fish working up under the gates to the dam board find the cross passages through the front end of the piers and finally reach the trap. It was expected that during freshets the current acting on the flashboard would always keep the lower ends of the gates above the surface of the water, and up to a certain point this expectation was realized, but at very high stages of the stream the large quantity of gravel in the water soon clogs and sinks the gates. As the gates are only two-thirds the length of the apron, however, and rise toward the lower end, the water shoots over them with such force that it is projected some distance below the end of the apron, and fish attempting to

B and *C*, single and double rows of piles, respectively.
D, downstream end of racks.
E, floor under racks.
F, open channel to trap.
G, walls of V-shaped approach to trap.
H, trap.
J, screen at head of trap.
K, openings in pier for passage of fish to *G*.
L, door in north side of V-shaped approach.
M, abutments.

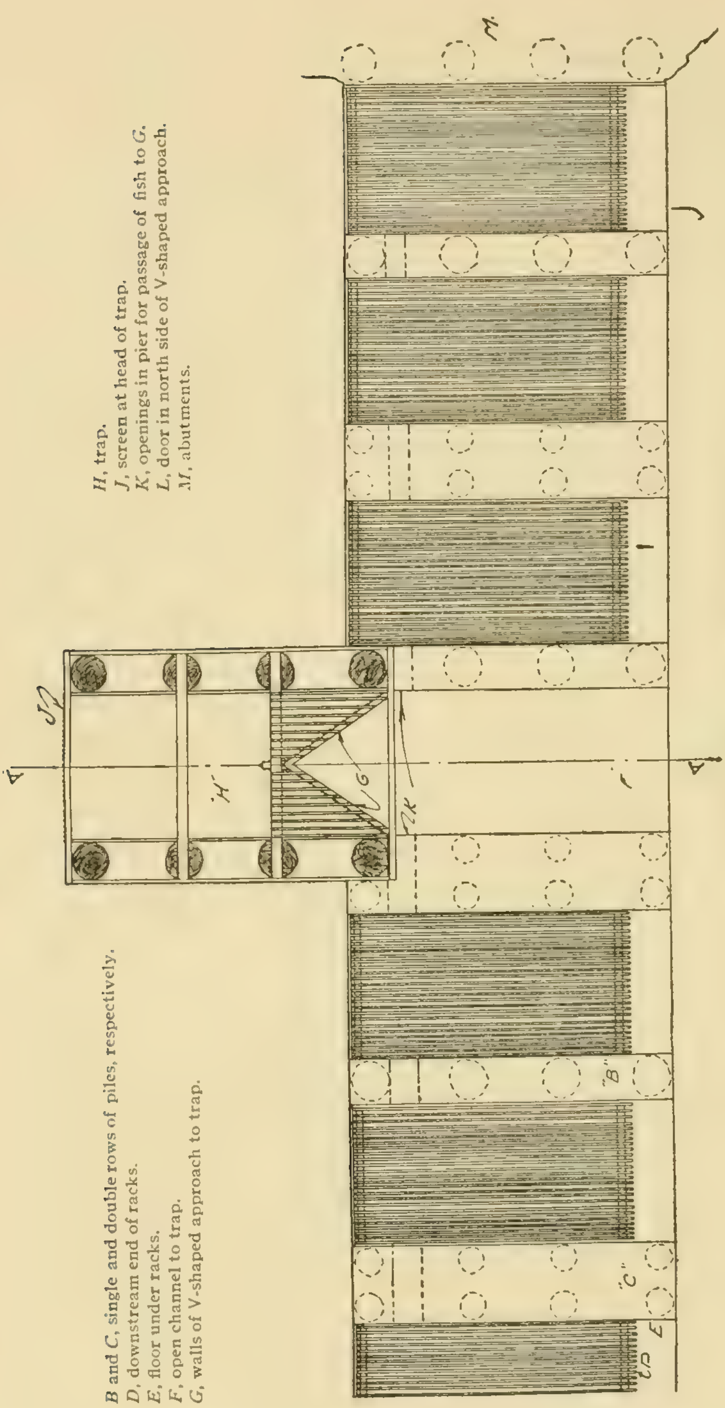

FIG. 2.—Plan of barricade in Phinney Creek, near Birdsview, Wash.

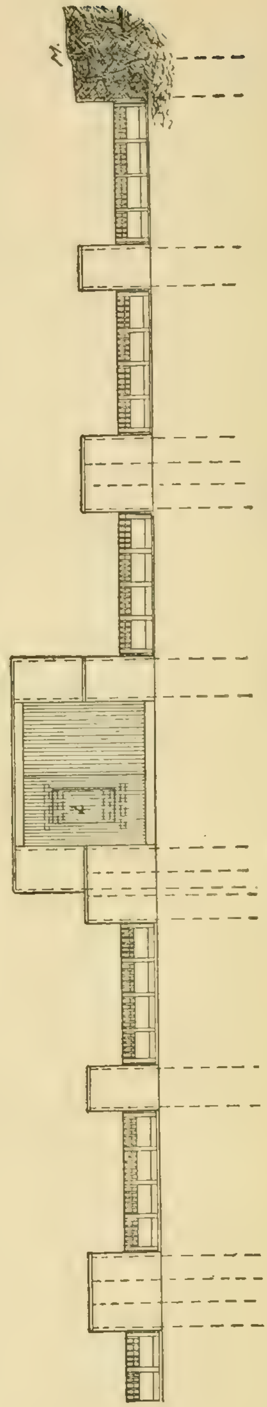

FIG. 3.—Front elevation of barricade shown in figure 2.

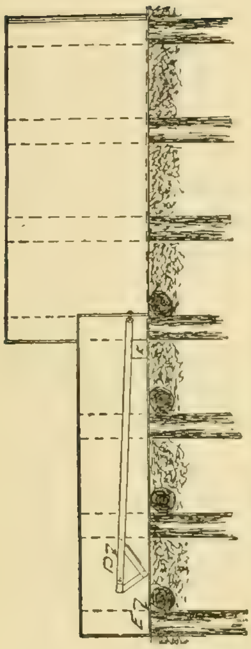

FIG. 4.—Side elevation of barricade shown in figures 2 and 3.

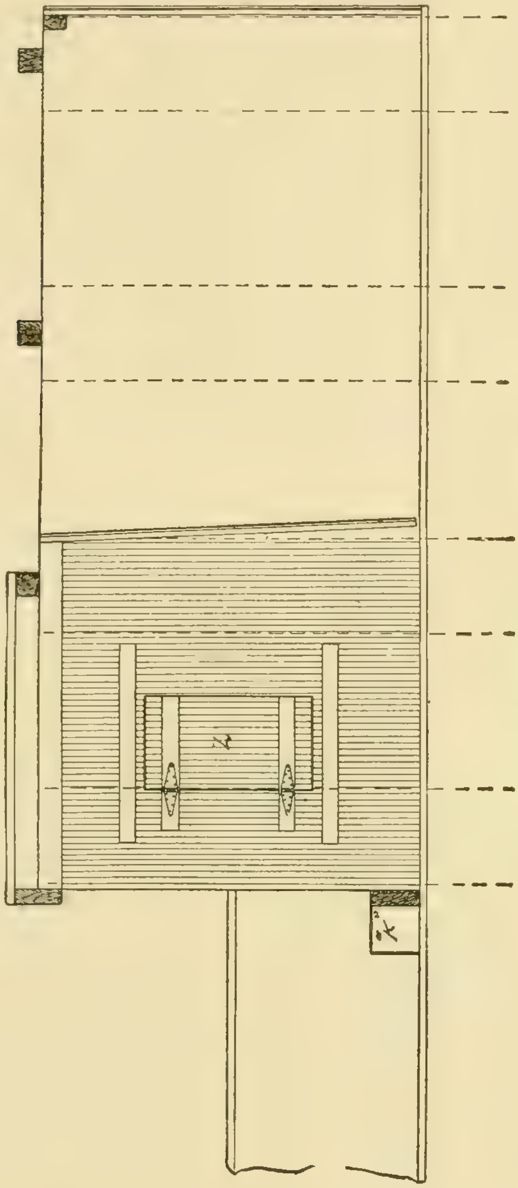

FIG. 5.—Section on line A–A of figure 2.

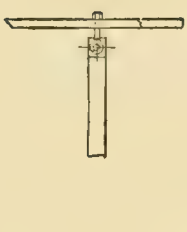

FIG. 6.—Detail showing method of fastening racks. (See figures 2 and 4, *D*.)

scale the obstruction fall far short of the ends of the gates. The barrier has been watched many times when fish were jumping and when the largest drift ran clear, and none has ever been seen to pass it.

By means of the dam boards entire control of the current can be had during ordinary stages of water and any desired quantity sent to any section of the barrier. Thus a strong current can be maintained through the trap section, leading the fish to it, and when it is desired to remove the fish from the trap the water can practically all be turned to some other section of the barrier.

One of the greatest difficulties in maintaining traps in the streams in this section is due to the tremendous quantities of gravel carried in the water during freshets, a sufficient amount being frequently deposited in front of a trap at such times to change the course of the stream. With the present form of barrier no trouble is experienced from this source, the insertion of the dam boards and the opening of one space at a time quickly clearing away the accumulated gravel.

The ninth and tenth piers were continued upstream by driving three additional piles above each. The piers form the sides of the trap. Its floor is a plank bottom, similar in construction to the apron, and the front is barred by 1¾-inch pickets placed 1¾ inches apart, the fish entering by the usual upstream V of pickets. To protect the trap from high water the two piers between which it is located were carried to a height of 8 feet. When it is desired to fish the trap, the gate at its head is closed and entrance is made from below by means of a door in the north side of the V.

The upper end of the fishway of the old dam was left in place, the narrow passage between it and the new trap protecting the spaces at the south end of the barrier from the current and from drift. These spaces have been racked above and below to form commodious pens for males and unripe females. The south end of the barrier is protected by a substantial abutment.

The maintenance of racks in Phinney Creek has been a very heavy item of expense in past years, and the trap was frequently carried away by freshets just at the height of the season, allowing large numbers of fish to escape and considerably reducing the season's take of eggs. It is believed the new barrier will stand any possible test that may be put upon it and will fish successfully in almost any stage of water. The design is to be credited to Mr. A. H. Dinsmore, superintendent of the station.

TAKING AND HATCHING THE EGGS.

Seining operations and spawntaking at California stations.—At the Baird station all the salmon are caught by seine with the exception of a very few taken in the trap in the upper rack. Owing to the swift current and the formation of the river banks the seine is always landed at one place, the rope attached to

the upstream end being hauled by steam engine and the lower or downstream rope by a whim operated by horsepower.

When a haul is to be made the seine is carried by boat upstream about 50 yards from the landing before it is paid out from the shore. The downstream rope is paid out automatically as the boat moves and is passed through a snatch block to keep the current from closing the ends of the seine until opposite the landing place, when both ends are drawn in at the same time. As soon as the seine has been laid out above the pool the engine is started, drawing the seine downstream toward the landing. When the last of the seine is in the water the whim is started and the lower end is also hauled down and in. A landing having been made, the ends of the seine are secured to pieces of rope fastened to pins driven into the ground. Hooks on loose ends of these ropes are slipped behind the corks of the seine. A trestle is placed under the rope to hold the cork line high above the water and thus prevent the salmon from leaping over it. The lead line is pulled upon the bank and thrown ovei iron pins to keep it from slipping back into the deep water.

The ends having thus been fastened, all the men are free to handle the fish, which must be quickly removed to prevent injury from crowding, this being especially true of the summer run when the water is warm. The men stand in the water and lift the fish from the net one by one until all have been looked over, handling them with the aid of heavy woolen gloves, and grasping them by the tail with the left hand while the right is placed just behind the pectoral fins. A gentle pressure of the fingers at this point forces out a few eggs if the fish is ripe; if not ripe it is thrown over the seine into the river. When a ripe female is found it is carried to the pens beneath the spawning platform a few yards distant, care being taken to hold it vent side up to prevent loss of eggs. The males are handled in a similar manner, the ripe ones being placed in pens near the females.

The seining crew are likewise the spawntakers, and after two hauls in the morning they strip the fish caught the day before. The ripe salmon of each day's catch are thus held over as a precaution against any possible immaturity of the eggs.

On the spawning platform is a frame 6 or 8 inches wide, with sides converging toward the bottom and open at one end, into which a spawning pan can be slipped. The pan is rectangular in shape, about 6 inches wide and 14 inches long, with slanting sides and flaring ends. This shape is preferable to the round pan because of facility in washing the eggs, it being possible to dip a thin stream of water into the pan the entire length of one side. The frame holds the pan secure and at the same time its slanting sides assist in guiding the eggs into the pan.

After washing, the eggs are placed in 6-gallon spawn buckets which have previously been filled with water. These buckets are made of galvanized iron, with a wire-cloth strainer inserted near the rim to permit the escape of surplus

water as eggs are added; they are painted inside with asphaltum, and are provided with covers. With the eggs in them they are placed on a platform which is built under water at sufficient depth to submerge about two-thirds of the body of the bucket, and thus maintain a proper temperature during water hardening. It is an essential feature of this platform that it be entirely independent of the spawning platform in construction. The period between the washing and hardening of the eggs is a critical one, and if they are jarred or disturbed there will be consequent greater loss in the hatchery.

In the spawntaking operations five or six male fish are first dipped from the pen and dropped on the floor, where they are allowed to lie until they stop struggling and may be more easily handled. Then several females are dipped out, killed by a blow on the head with a piece of iron piping, and laid in the dead box. The bottom of this box is inclined and has a narrow slit at the lower end, through which any eggs that may escape from the fish will fall into a pan underneath, where they will be fertilized by occasional applications of milt. The dipping and killing continues until all the fish are stripped, males always being kept on the floor in order to have several ahead of the spawntakers. After being stripped the best-appearing males are returned to the pens, where they usually recuperate and are again used to supply milt.

The female fish is grasped by forcing the fingers through the gills and the thumb into the mouth, the hand being protected by a stout leather glove. The man who does this, the headholder, stands, holding the fish vertically. The spawntaker, in a kneeling position, seizes the fish by the tail, bending its body over the pan, while with a sweeping motion he makes an incision in the thin side of the belly beginning near the pectoral fins and extending to the anal. The incision is usually made with a pocketknife, the blade being held between the thumb and index finger within one-half to three-fourths inch of its extreme point to prevent cutting too deep. Most of the eggs follow the knife and fall into the pan, the remaining ripe eggs being released by running the fingers into the body cavity. As soon as the eggs begin to flow into the pan milt is forced over them and they are stirred by the spawntaker with a few movements of the hand. They are then passed to the washer. The milt of one male may serve for several pans of eggs, but it often happens early in the season that several males are required to one pan.

As soon as the washer receives the pan of eggs he dips the edge of it in the river, the inflowing water causing the eggs and milt to boil up. The eggs at once settle back and the milt is poured off over the side of the pan. Ordinarily two such dips suffice to clean the eggs, after which they are poured into spawn buckets, and at once settle to the bottom, the surplus water escaping through the wire-cloth strainer near the top. Spawning operations usually consume about an hour. After water hardening the eggs are carried to the hatchery, about 200 yards distant, and turned over to the hatchery crew.

FIG. 21.—Spawntaking operations, Baird, Cal. The fish (chinook salmon) are dipped from the pen, killed by a blow on the head, and passed to the spawntakers. The eggs are taken by opening the abdomen, and the stream of eggs may be seen in the picture following the hand making the incision.

FIG. 22.—One method of stripping steelhead trout. Since this fish normally does not die after spawning, the ripe fish are not killed as are the salmon, and they are so large, and so powerful in their struggles, that the strait-jacket here shown is sometimes resorted to.

The spawning operations at Battle Creek and Mill Creek are practically the same as those at Baird, and the seining differs only in minor details to meet local conditions.

The method of taking eggs by incision has many advantages over the older practice of expelling by hand, chief among them being the larger number of good eggs secured and the higher percentage of impregnation. There is also a great saving of time and labor, and, as all of the Pacific salmons die after once spawning, the killing of them in the process of taking the eggs merely hastens the end, and constitutes no loss of adult fish.

The eggs of the Pacific salmons are comparatively large, ranging in diameter from one-fourth inch for chinook to one-fifth inch for sockeye. Fortunately, however, these large eggs do not require the same treatment and care as do those of the other Salmonidæ, but may be placed 12 to 20 deep in wire-cloth baskets, 30,000 to 50,000 to the basket, water temperature being an important factor in deciding the quantity. The baskets, rectangular in shape, conform in width to the troughs; the latter are of the Williamson type (up-current), the flow of water to each trough varying with local conditions at the different hatcheries from 8 to 20 gallons per minute.

Local practices in different regions.—Experience seems to indicate, with regard to the sockeye, or red salmon, that there is an advantage in bleeding the fish before stripping, thus obviating a flow of blood with the eggs when the incision is made. It is therefore now customary at sockeye stations to decapitate or else cut off the tails of the female fish as the first step in the spawn-taking process. At Baker Lake, Washington, the practice is as follows:

The fish, which have been brought to the pens usually the day previous, are dipped out one by one, decapitated, and dropped upon a draining rack, where water is thrown over them to cleanse them for handling by the spawn-taker. The latter impales the fish on a short spike conveniently located to hold them over the pan while he makes the incision and removes the eggs. Two men are occupied in the work so far. A third fertilizes and washes the eggs, then conveys them to the hatchery. A million eggs may be secured in this manner in one forenoon by one such crew.

Although not suitable for canning or for the market, the sockeye at this period is edible and many are taken by local residents for food. Indians camp at some of the stations and preserve large numbers of the salmon. The majority of those killed, however, go to waste. At the Battle Creek station in one season it is not an unusual thing to bury during the spawning season 15,000 to 20,000 pounds of fish.

A convenient and economical method of separating dead eggs of salmon from living ones is the use of a salt solution.[a] If a basket of eggs is emptied

[a] O'Malley, Henry: Salt solution as an aid to fish culture. Transactions of the American Fisheries Society for 1905, p. 49.

into the solution, the unfertilized and dead eggs rise to the surface, where they may be quickly skimmed off. The method is not applicable in the manipulation of small quantities of eggs, but is very useful when, for some cause, there is an abnormal loss. It has not been successfully extended to the eggs of species other than the chinook, silver, and humpback salmons.

At the Baker Lake station, operated primarily for the propagation of the sockeye salmon, both sockeye and silver salmon are captured by means of a pound net as they enter the lake, but as the fish are not ripe at this stage of their upstream passage it is necessary to hold them until the spawning season. For this purpose a slough or bay at the head of the lake has been inclosed by racks and webbing to make a pound about 20 feet wide and 500 feet long, with an average depth of 6 feet. The entire bottom area is of soft mud; in it are two hollows of a maximum surface area of 300 feet and 400 feet, respectively, where the water is approximately 12 feet in depth. The water supply, from 800 to 2,400 gallons per minute, is derived from several small mountain creeks fed by glaciers and snow, and from springs.

This has proved an ideal place in which to hold salmon while their eggs are maturing. As many as 8,000 fish have thus been confined for thirty days and 6,000 for three months. After remaining in the inclosure for three or four months the fish are as clean and free from abrasion as fish that have not been penned. A noticeable fact, however, is that very few of these salmon ripen until October or November, while in previous years the spawning season has occurred during September and before October 15. The difference is attributed to the low temperature of the water in the inclosure, which remains from 6 to 8 degrees below that of the natural spawning beds of the lake. (During the summer the average water temperature on the spawning beds is about 56°.) The success of the impounding of the salmon is attributed to the low temperature of the water.

Silver salmon, as well as sockeye, have been successfully impounded at Baker Lake. A few impounded chinook, however—never more than 12 at a time—fungussed rapidly, and after three weeks usually died before the eggs were taken.

MARINE FISH CULTURE.

COD, POLLOCK, AND FLATFISH.

On the New England coast the Bureau maintains three stations, for the hatching of marine fishes and the lobster.

Of the fishes the cod is first in importance. Its cultivation consists principally in hatching eggs obtained from market fish, the fish being stripped either by the fishermen or by the Bureau's spawntakers. The latter are daily distributed among the fishing vessels for the double purpose of stripping ripe fish as fast as hauled aboard and of collecting and caring for all eggs the fishermen may

have taken. Coming as it does during the winter months, from early December to March on the Massachusetts coast and extending through March and April on the Maine coast, the spawning season is a trying one for the spawntakers, who must share many of the dangers and hardships of the fishermen.

At the Woods Hole station advantage has been taken of the presence of a large salt-water reservoir under the hatchery to test the Norwegian method of obtaining eggs. By this process adult fish are penned and allowed to spawn naturally. The eggs float to the outlet, where they are caught in a receptacle placed for the purpose, and thence are transferred to the hatching boxes. It has been demonstrated that a larger percentage of fertilized eggs per fish can be obtained thus than by the former method of stripping penned fish. The increase is not due to a higher percentage in fertilization, but to the fact that in the case of the penned fish there is an almost unavoidable loss of eggs extruded in the crates. Both of these methods are an improvement over nature, in that the eggs are protected from the time of extrusion until they have hatched and the surviving parent fish are returned to the ocean. This is fish culture in the usual sense and not purely conservation of an otherwise waste product, as is the collection of eggs from market fish.

Prior to the spawning season for cod, or from the middle of October to the latter part of December, spawntakers are distributed among the pollock fishermen, and from the eggs thus collected many millions of pollock fry are hatched and distributed annually.

The cultivation of flatfish is conducted on a more extensive scale than any other marine fish-culture work. The adult fish are taken from the fyke nets in which captured, usually the Bureau's own, directly to the hatcheries, where they are placed in tanks and held until they have spawned, the eggs being removed daily from the tanks to the hatching apparatus. It is possible to spawn flatfish artificially, and eggs are sometimes obtained in that way.

LOBSTERS.

Lobster culture also, as conducted by the Bureau, effects a saving of an otherwise lost resource, berried lobsters purchased from the fishermen furnishing eggs for the hatchery and being later returned to the ocean. At the Boothbay Harbor, Me., station the parent lobsters are held until the eggs are ripe in a pound similar to those used by the lobster men; and as it has been found that eggs taken late in the fall or early winter do not hatch successfully, one such pound is utilized to hold some 10,000 or 12,000 lobsters throughout the winter. The losses of lobsters during the period of confinement are only normal, and the quantity and quality of the eggs are superior to those obtained from freshly caught stock. It is noticeable also that the eggs of the impounded stock hatch almost simultaneously and somewhat earlier than those from freshly caught lobsters, undoubt-

edly because of the warmer, shallow, inshore water. By the middle of April the eggs are sufficiently well advanced to be removed from the parent and put up in the hatching jars; and as at this time the lobsters become quite active in a rising water temperature it is quite important that they then be removed to avoid serious losses from mutilation.

The removal of impounded lobsters is effected at low tide, the flood gates being opened and a portion of the water drawn off with care to retain enough water to protect the lobsters from exposure. Men in dories then go about the shallow portions of the pound picking up the lobsters on ordinary clam forks or hoes, the sharp teeth of which have been blunted. It was formerly the custom to use a drag seine for gathering the lobsters, but taken in such quantities they mutilate one another and it has been found preferable to remove them by hand. After a portion of the stock has been removed the water is drawn still lower, until finally only a small area of the pound is flooded, and the remaining lobsters are removed.

As it has not been possible to transport lobster eggs successfully when detached, the berried females are always taken to the hatchery to be stripped, the transfer being made in the wells of fishing smacks or the Bureau's vessels. From this time to the close of the season in July berried lobsters are collected from the fishermen and transferred to the hatchery to be stripped. Immediately after the close of the season the collection of fresh berried lobsters for stocking the pound is begun and continued into November.

It is unquestionable that the impounding of lobsters as practiced in Maine is superior to any other present method of holding the adults for a length of time. The character of the Maine coast, with its numerous natural inlets and its unusual rise and fall of tide, affords especial advantages for the use of pounds. When these conditions do not exist, however, recourse can be had to cars, although data thus far obtainable fully demonstrate that a larger number of lobsters can be held for a longer time and with a smaller percentage of loss in pounds than in cars.

Contrary to the custom of the pound fishermen, the ice on the surface of the pound operated by the Bureau of Fisheries is removed from time to time during the winter, with the result that a much larger percentage of lobsters is found in the spring. It has been observed that the rising and falling of ice with the tide frequently crushes lobsters that happen to be in the shallow water near the edges of the pound, and removal of the ice at intervals obviates this difficulty.

Experiments have been made as to the poundkeepers' practice of inserting wooden plugs in the claws of penned lobsters to prevent their mutilating one another. For lobsters intended for market the procedure seems suitable, though it results in an unsightly discoloration of the muscles. There seemed

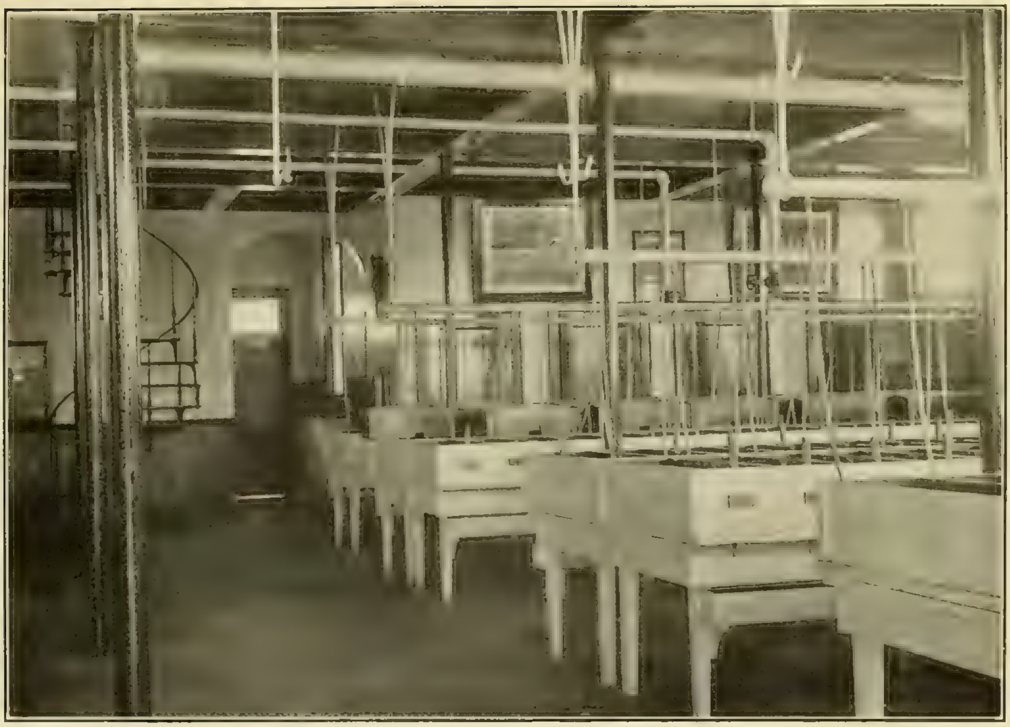

FIG. 23.—Equipment of McDonald automatic tidal boxes, for hatching cod, Boothbay Harbor, Me. Shows boxes lifted out of troughs and bottom upward on farther tables. The bottom is of scrim, and by means of cleats is held 1½ inches above the bottom of the trough at the center. By an arrangement of partitions at the head of the trough the eggs receive the supply of water through the scrim bottoms of the boxes, also through a small hole in one end of the box. The distinctive feature of the apparatus, whence it is called "tidal," is the automatic siphon outflow, by means of which the water is alternately drawn down and replenished. Standpipe with siphon cap is shown in near troughs; waste trough below.

FIG. 24.—Berried lobsters, taken from pound at Boothbay Harbor station (Maine), in course of transfer to wells of the steamer which is to convey them to the hatchery for stripping.

to be a question, however, whether it would be feasible with the impounded stock of the Bureau destined for liberation in the open waters after removal of their eggs. The experiments showed that out of 2,110 lobsters removed from the pound, all of which had been plugged when put in, 742 had lost both plugs, 563 had lost one plug, and 605 retained both. The warm weather when they are first confined, however, is their most active period, when the plugs do most good. Mutilation is thus prevented and the plugs apparently work no permanent injury to the lobsters.

It is important in the impounding of lobsters to take precautions, so far as possible, for the exclusion of eels, which have an especial liking for the eggs and will strip a female lobster in a very short time. Even with all precautions it seems impossible to exclude eels entirely; it is probable that many enter when small and grow up in the pound.

The rearing of lobster fry to the fourth molt, as practiced by the Rhode Island Fish Commission and so admirably set forth in a paper read at the congress,[a] has not as yet been taken up by the Bureau, but is doubtless feasible at the Boothbay Harbor station. Before the first experiments in this direction at Boothbay it was thought that owing to the lower temperature of the water in this more northern latitude the periods of molting would be prolonged and the feeding and care of the fry consequently attended with abnormal losses. It has since been found that this difficulty can probably be met by installing the rearing plant in a lobster pound, where the temperature is higher and more even than in the open waters. The Bureau therefore hopes to enter upon this undertaking in the near future, for the purpose of rearing a portion of the lobster output. To attempt to rear to the fourth molt the entire product of the Boothbay station would involve an expenditure far beyond present financial resources.

MEASURING AND COUNTING FISH EGGS AND FRY.

Immediately after water hardening, for a short period varying with the species and water temperature, the careful handling of fish eggs is not injurious. During this period their numbers may be very definitely ascertained by the use of any receptacle suitable for a measure, the capacity of the receptacle having first been ascertained by counting the whole or a fractional part of its contents.

For eggs of the trouts and those of smaller size an apothecary's graduate or the ordinary graduated quart or pint measure is commonly used. For large quantities the long-handled dipper used in transferring them to the hatching apparatus may be advantageously utilized. As many eggs as possible are poured into the measure, nearly all of the water being forced out over the rim.

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[a] Mead, A. D.: A method of lobster culture. Proceedings Fourth International Fishery Congress, Bulletin of the Bureau of Fisheries, vol. XXVIII, 1908, p. 219–240, pl. VII–XI.

Unless the eggs are to be transferred to a hatchery beyond the jurisdiction of the shipper, the eggs may not be measured until a more convenient time, it being possible from long familiarity with the capacity of the apparatus in actual use to estimate quite accurately the number of eggs on hand at any time. Providing they are spread uniformly, the number of eggs to a square inch is a fairly accurate basis for ascertaining how many eggs are on each tray. Some fish culturists prefer to ascertain the actual number of eggs on hand by weighing them after having determined by actual count the basis for such calculations.

These methods are especially applicable to the heavy eggs of the Salmonidæ, and may be employed not only after water hardening but also at any stage of incubation after the eggs are eyed up to a day or so before hatching, at which last stage a measurement closely approximates the number of fry that will be in the subsequent hatch.

Eggs hatched in jars are usually measured by means of a graduated scale in the form of a square made of wood, the units indicated on the long leg of the square. The square is adjusted to the jar as shown in figure 1. The scale reads from the bottom line upward, the first or bottom line being at a height corresponding to the level attained in a jar by a measured half pint of water, and each line represents the number of eggs of a given species as established by actual count from a measured half pint. The dead eggs will have been from time to time siphoned off and when the remainder are fully developed or about to hatch the scale is applied to each jar and a very careful measurement is made to ascertain their number. The number of fry available for distribution will be approximately the number of eyed eggs in the jars just before hatching, as the mortality after this stage of development is usually inappreciable.

A novel method of obtaining the number of eggs in a given lot has lately come into use, and as the work can be done without counting a large number of eggs, has proved especially valuable in dealing with eggs of small size at field stations where no measurements have been established. This method, devised by Mr. H. von Bayer, architect and engineer of the Bureau, employs a gauge which quickly gives the diameter of the eggs, knowing which it is possible by reference to a diagram to determine at once the number of eggs to the quart.[a]

In the keeping of accurate hatching records it is important that the basis for computations be ascertained immediately before any general measuring methods are applied because it is well recognized that eggs of most species vary in diameter with stock from different waters and that eggs from any given collecting station vary at different periods of the spawning season, those taken at the height of the season being larger and more uniform than those taken earlier or toward the close of the season. For instance, brook trout eggs taken at a

[a] von Bayer, H.: A method of measuring fish eggs. Proceedings Fourth International Fishery Congress, Bulletin of the Bureau of Fisheries, vol. XXVIII, 1908, p. 1009–1014.

particular station may run 250 to the fluid ounce during the height of the season, while the first take may have run 300 to the ounce and the last eggs of the season may average 400 or more to the ounce. These variations make it necessary frequently to establish a new measure for ascertaining the actual number of eggs. There is also to be taken into consideration the fact that eggs of almost all fishes increase in size from 4 per cent to 15 per cent according to the species, from the time they are water-hardened up to the time they are about to hatch.

This fact, coupled with the fact that eggs of the same species vary in size at different sources of supply and periodically at the same source of supply, is a point in favor of the von Bayer method of computing the numbers of eggs of small diameter.

Sac-absorbed fry and advanced fry of the trouts, landlocked salmon, etc., may be measured in the same manner as are the eggs—in an apothecary's graduate or other container, straight vertical sides being preferable to the flaring sides of the ordinary glass graduate. The ordinary graduated half pint or pint cup used by cooks is a very convenient measure. The fry are poured in until the measure is overflowing with them to the exclusion of practically all the water, the filling and emptying being done quickly. Actual count of the number in one measure establishes the basis for computation. The growth during this period being very rapid, however, a new unit must be determined daily.

The numbers of fingerlings are ascertained by actual count of each lot as dipped a few at a time from trough to transportation can or other receptacle by means of a small hand net of tightly stretched bobbinet.

TRANSPORTATION OF EGGS.

To equalize and facilitate the work of the hatcheries it is customary to transport, sometimes to considerable distances, both green and eyed eggs from one station to another, thus effecting the distribution of fish through the distribution of eggs. Several auxiliary stations are maintained on the Great Lakes solely for hatching eggs received from Northville, it having been found economy to transfer to them as eyed eggs the portion of the Northville station output destined for distribution to waters in those localities. Both green and eyed eggs are also shipped to state hatcheries and the latter to foreign countries.

The methods of conveying green eggs from the field where collected vary to suit conditions. The stations at which eggs of commercial fishes are hatched in large numbers are usually located conveniently to the source of supply so that it is possible to carry the freshly fertilized eggs to them in the pans, buckets, or other receptacles which constitute the equipment of the spawn taker. It often happens, however, that the eggs must be held in the field or be in transit for two or more days, and in such cases a packing case is employed.

USUAL STYLE OF PACKING CASE.

For ordinary purposes a packing case consists of a wooden box which will accommodate a stack of trays and an ice hopper, with 2 to 4 inches of insulation or packing on all sides and under the tray stacks. The frames of the trays are made of light, soft wood, usually white pine, 5/8 inch by 7/8 inch or 7/8 inch by 7/8 inch, over which is tightly stretched a bottom of canton flannel, nap side up, or of heavy cheese cloth, with perforations in the cloth to facilitate the passage of water.

For long-distance shipments it is customary to make the bottoms of the trays of wire cloth painted with turpentine asphaltum, over which canton flannel or cheese cloth may be spread before putting the eggs upon them, and a thin layer of moss under the cheese cloth in addition is advocated by some fish culturists. The soft spongy bed of moss prevents concussion in handling and retains moisture, while at the same time it allows a sufficient circulation of oxygen and free passage for water from melting ice, etc. For very long or warm-weather shipments it is sometimes advisable to use a case with double sides, with insulation between, the space between the inner case and stack of trays being filled with ice.

The ice hopper is about 3 or 4 inches deep, of the same length and width as the tray frames, and rests upon the top of the stack. Its bottom is perforated to allow a drip from the ice through the trays and thus keep the eggs constantly moist and cool. Double cases, the length twice the width, arranged for two stacks of trays side by side with a partition between them, are sometimes used in the Pacific salmon work.

The fish culturist often works in isolated places and must use the material which is most accessible and economical. Moss is therefore very generally used for filling the space between the stack of trays and the packing case; mineral wool, leaves, sawdust, and shavings also well serve the same purpose, though with ice in contact with the inside lining of the outside case mineral wool is objected to because when damp it has a tendency to sag. Any of these materials may be used for insulation in the long-distance cases. Cork board insulation, also, is very efficient and of lighter weight than the others, but it has not been tested so fully as have shavings, at present the material most popular with caretakers.

The cover to the case may be screwed on, but for shipments requiring the renewal of ice it is customary to provide a hinged cover fastened with hasp and staple.

ADAPTATIONS AND VARIATIONS OF METHOD.

Eyed eggs of the Atlantic and Pacific salmon and of the steelhead trout have all been successfully shipped in the ordinary case, but the method of packing eggs of the Atlantic salmon at the Craig Brook (Me.) station has the special

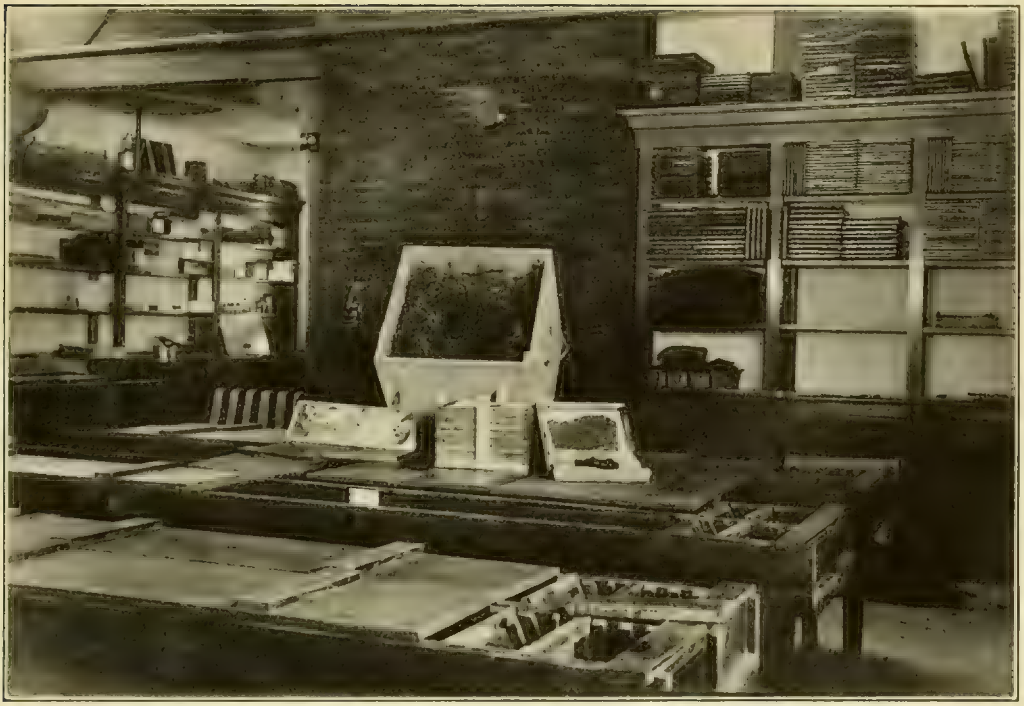

FIG. 25.—Box of trout eggs just opened. Showing ice hopper at left, stack of trays which have been taken out of the moss in center of box, and one tray with covering of mosquito net and moss removed. This is the common method of packing for ordinary shipments. (Described on p. 742.)

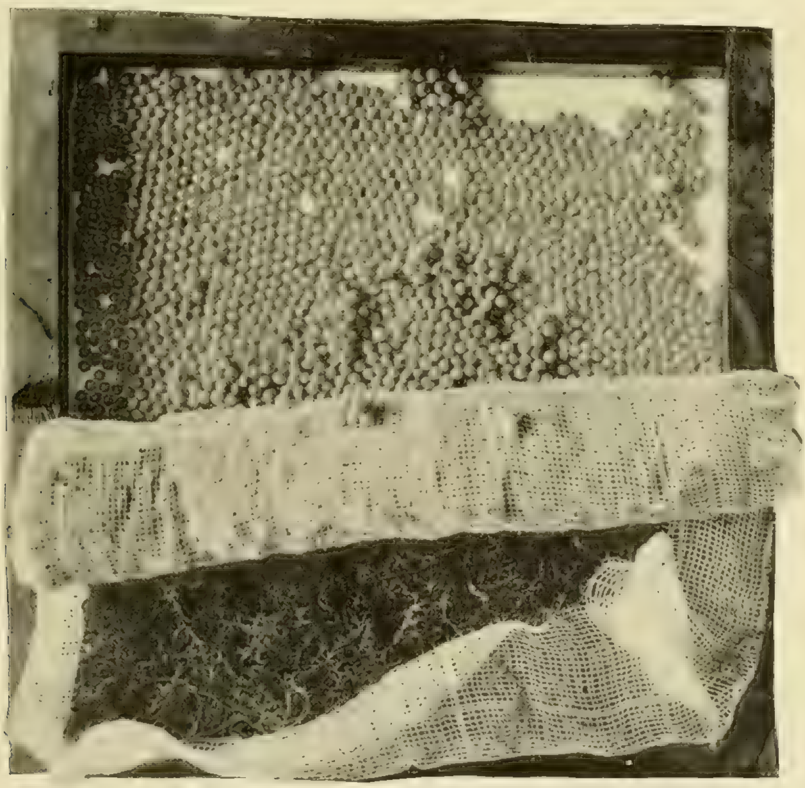

FIG. 26.—Tray of trout eggs with mosquito net and moss in which packed.

advantage of making a comparatively light package—a factor of great economic importance in transportation. The outside case may be an ordinary box of suitable dimensions. In it are packed, surrounded by moss, several boxes made of ⅜-inch boards, and usually 12 inches wide by 15 inches long by 3½ inches deep, each box containing a mass of 10,000 to 20,000 eggs in mosquito netting, with moss around all sides. No ice is used, care being taken that the packing be done in a temperature below 50°, that all packing material be kept in a place slightly below freezing point, and that the moss in which the eggs are packed be sprinkled with snow. This method of packing is an economical one for shipments of eggs of Salmonidæ during cold weather, but can not advantageously be used for eggs of spring spawning fishes unless there is available a cold-storage room in which to do the packing. Recently the superintendent of the Baker Lake (Wash.) station, who has had occasion to ship eggs of steelhead trout and Pacific salmon in warm weather, has packed them in light cases with alternate layers of moss, and then placed two tiers of these thin cases side by side in an outer case with a large hopper of ice over the whole, the drip passing down between the two tiers of inner cases. The chief advantage of this case for long-distance shipments is in the fact that less ice is required than in other forms of cases using ice, with a consequent saving in transportation charges. It can also be used in warm as well as cold weather. It is believed it will be economy to extend the use of this case in packing eggs of other species of Salmonidæ.

Green eggs of the brook trout and chars are carried in spawning pans or buckets, the spawntakers sometimes, by the use of a neck yoke, carrying two pails of trout eggs several miles. It is possible to ship the green eggs a half day's journey without serious loss, but it is preferable to eye them at places convenient to the traps where the parent fish are caught, after which they are packed by the ordinary method.

For grayling eggs cheese cloth is used for the bottoms of the trays instead of canton flannel and it is preferred by some in packing other kinds of eggs because it permits of a better circulation of air and is not so apt to hold water. No moss is used on the trays over the eggs, but only mosquito netting, as the eggs will not stand pressure. Both the hopper and the chambers around the tray stack are kept filled with ice, thus maintaining in warm weather a temperature of about 40° F.

In transferring by messenger large numbers of eggs, whether green or eyed, of any species, it is customary to omit the packing on and around the trays, ice being used to regulate the temperature.

Eggs of the shad and other species of which the period of incubation is but a few days are usually shipped within forty-eight hours after being collected. Shad eggs are seldom shipped for more than a few hours' travel. For this

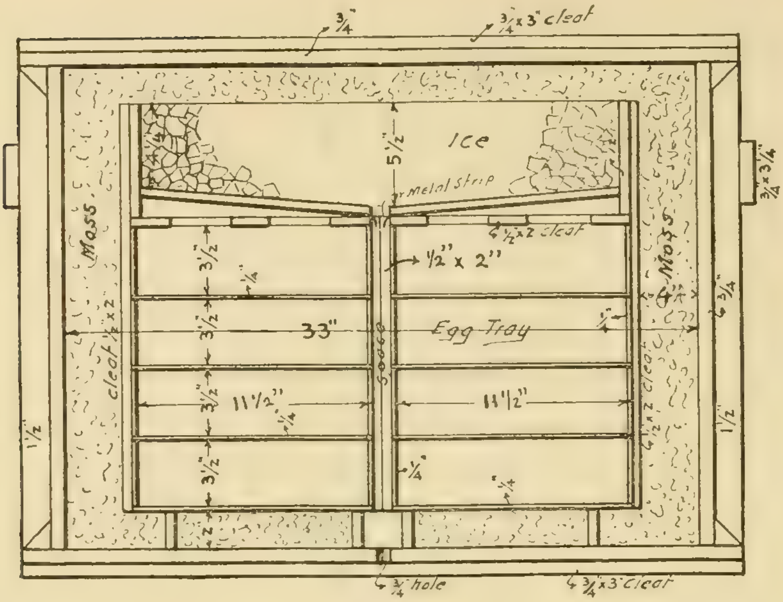

FIG. 7.—Atkins-Dinsmore shipping case. Longitudinal section.

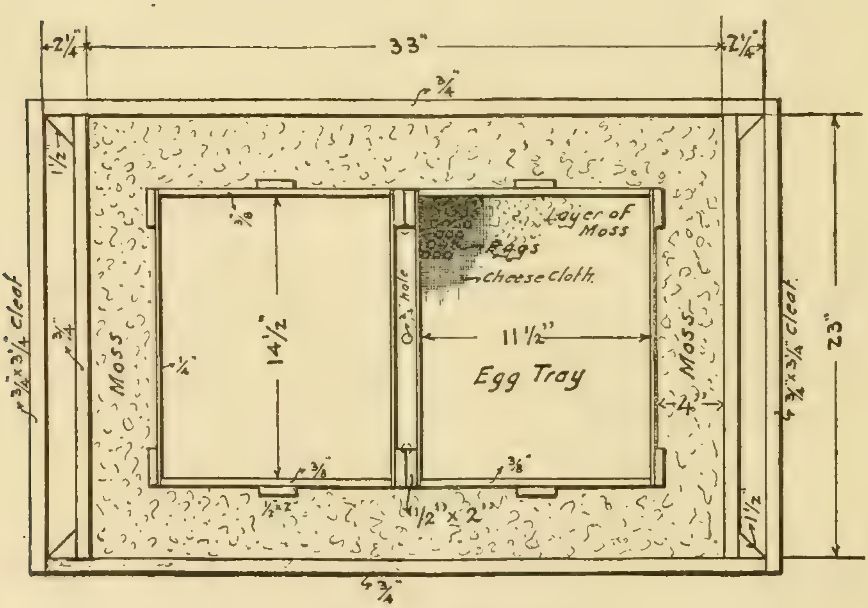

FIG. 8.—Atkins-Dinsmore shipping case. Plan.

purpose they are laid in cheese cloth on wire-bottom trays, between wooden frames also covered with wire cloth, strapped together, and shipped without further packing.

Experiments at Havre de Grace, Md., seem to demonstrate that it is practicable to pack eggs of the white perch in the ordinary trout egg case with ice hopper and ship them on journeys of thirty-six hours' duration without apparent injury. Two lots of green eggs taken at a temperature of 56° and 70°, respectively, and held in trout egg cases for twenty-four to twenty-six hours, hatched as well as eggs placed directly in the hatching jars. In the first experiment there was no change in temperature, but in the second experiment there was a fall from 70° to 64°. White perch eggs to the number of 3,000,000 have in several instances been shipped by express from Havre de Grace, Md., to Washington, D. C., a half day's travel, in four McDonald jars packed in sawdust, ice being used in the packing when the air temperature seemed to require. The jars were equipped with the usual glass tubes, which extended above the packing, but whether this provision for aeration was necessary has not been tested. To insure proper aeration, however, it would seem advisable, with present knowledge of the subject, not to ship large numbers of white perch eggs in water for travel of four or more hours without a caretaker.

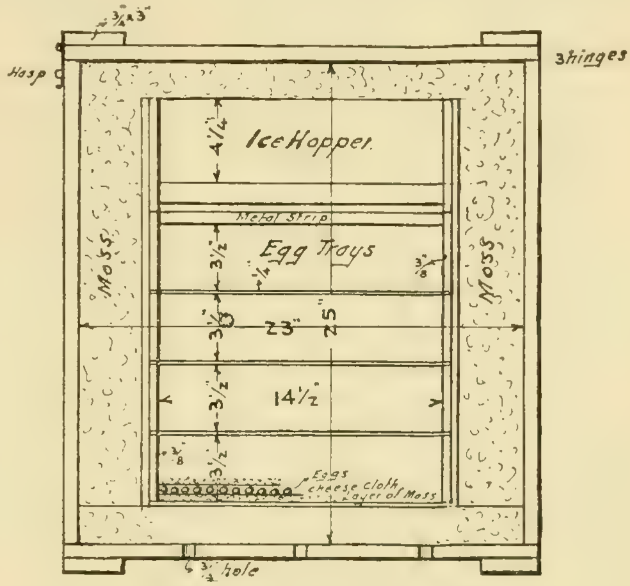

FIG. 9.—Atkins-Dinsmore shipping case. Cross section.

Attempts to transport yellow perch eggs on trays have not given satisfactory results, but it is apparently possible to carry them successfully almost any reasonable distance in the ordinary transportation cans, 1 to 2 gallons of eggs to 8 gallons of water, the proportion varying with the distance to be traveled, and care being taken to aerate and temper the water.

Green pike perch eggs may be carried from near-by collecting grounds to the hatchery in tubs or transportation cans, care being taken to renew the water frequently, to keep it well aerated, and of a proper temperature. Ice must be prevented from coming in contact with the eggs, because, unlike most

other eggs, they are very sensitive to such exposure. Half-barrel fish kegs or kits with one end knocked out and iron handles attached make very good and economical vessels in which to transport pike perch eggs. It is customary to insert a wire-cloth drain in the top of the kit on one side and the kits are asphalted inside. Canvas is thrown over the top to serve as a cover. When the eggs are held over night in these kits it is expected to supply them with running water whenever possible to do so; otherwise the water must be periodically renewed or aerated. At some of the field stations a pipe arranged with pet cocks and rubber tubing for supplying water to a number of kits or transportation cans saves much labor in the matter of aerating eggs which must be held for a day or more.

Pike perch eggs collected at a distance from the hatchery are conveyed thereto in the usual transportation case on trays, a small amount of ice being placed on the top tray, which is substituted for the usual ice hopper; an inch space around the sides of the stack is also filled with ice. Ice over the stack must be used sparingly or the green eggs may be injured by the cold water where it trickles upon them. For large shipments it is customary to have a caretaker accompany the packages to regulate the temperature, etc., the use of moss on the trays as well as the insulation material then being omitted.

Since eyed pike perch eggs are usually shipped during the month of May, for safety ice is used around the stack of trays as well as in the hopper, even on a two days' journey.

Whitefish eggs are transported from the field of collection by both of the methods employed in the transfer of pike perch eggs, although they do not require quite so much attention. Eyed whitefish eggs are packed on trays in the ordinary way.

The fields for the collection of lake trout eggs being widely distributed, it sometimes happens that green eggs are held in transportation cases for several days before their arrival at the hatchery. They carry as well laid directly on the wire-cloth bottoms as on a layer of cheese cloth. No packing is necessary if they are in the care of an attendant, since the latter can regulate the temperature by the use of ice and with water of the proper temperature, the trays being removed and sprinkled at least once in twenty-four hours.

In packing lake trout eggs for short distances, say up to a thousand miles, the ice hopper is omitted. Mosquito netting and moss are put on in the usual manner and the top of the moss is slightly frosted before the trays are stacked on the baseboard. A light piece of lumber is used in place of the ice hopper and fine shavings are solidly packed under, above, and on all sides of the stack of trays. For the longer shipments the ordinary ice hopper is used, fine shavings being placed around the stack of trays for insulation.

In the handling of eggs of the cod and other marine fishes a so-called kettle, oval and with a concave top, is used to retain them on board ship in a choppy sea. The water in which they are kept must be frequently changed or aerated. The eggs are shipped to the hatchery in large fruit or butter jars, rockweed or moss, together with ice or snow, being used in packing them. It is regarded as impracticable to ship eggs of marine fishes for travel of more than two or three days.

ARGENTINE CASE.

While the various methods above described have all been successfully employed in the transportation of eggs across the United States and also to Europe without an attendant, shipments of eggs to points south of the equator, usually leaving this country in winter and arriving at their destination in summer, have called for more than usual attention to the methods of packing them, and a caretaker is quite essential.

A highly efficient form of shipping case has been developed during the past few years for the transportation of eggs of the Salmonidæ from this country to Argentina. It is 3 feet 6 inches long, 2 feet wide, and not exceeding 30 inches high, outside measurement, and is constructed of selected tongued and grooved lumber. It has double walls, with bottom and top common to both, the 2-inch space between the walls being filled with nonconducting material, preferably tightly packed shavings. Between the inner wall and the stack of trays is a 2¾-inch space for ice, separated from the trays by perforated zinc. Between the latter and the trays, in a ¾-inch space, are the vertical supports of the zinc, viz, double corner supports, one being ½ by 1½ inches, the other being ½ by 1 inch; two intermediate supports of ½ by 1 inch material, which are provided on either side of the case and one at each end; and cross braces of ½ by 1 inch material, which extend from the uprights to the inner walls of the case.

The ice hopper, 3 inches in depth, and having the same outside dimensions as the trays, rests upon the latter and fills the space between the uppermost tray and the top of the case. It has a perforated zinc bottom, and, to facilitate handling, cleats of small ropes are attached to it. The top of the case is insulated with a 2-inch thickness of nonconductor covered with sheet zinc, this insulation fitting closely into the chest when closed, and thus covering not only the ice hopper but the ice spaces around the sides as well. In the bottom grooves lead to a ¾-inch drain hole, which is provided with a cork. Two cleats ⅞ by 3 inches are attached lengthwise to the bottom on the outside.

The trays are one-half inch deep, 27 inches long, and 9 inches wide inside measurements, the frames being of ½ by ¼ inch material. The bottom of each

tray is covered with wire cloth no. 25 gauge, about 12 meshes to the inch, stretched tightly to prevent sagging and consequent uneven distribution of the drip water. A narrow binding of cloth is tacked around the bottom of each tray to prevent the wire edge from catching on the mosquito net covering of the tray beneath. On the inside ends of the trays are fastened short lifting cleats, and wedges hold the trays securely in place. The bottom tray rests on three 1½-inch cleats extending lengthwise of the case, one at either side and the other in the middle. It is important to have the trays of uniform size, that they may be interchangeable.

The trays and interior of the case are coated with asphaltum. To facilitate opening from either side, four hasps are used, two on each side of the case. Two rope handles side by side are placed on each end of the case, with a cleat of three-fourth inch material just above the holes for each handle.

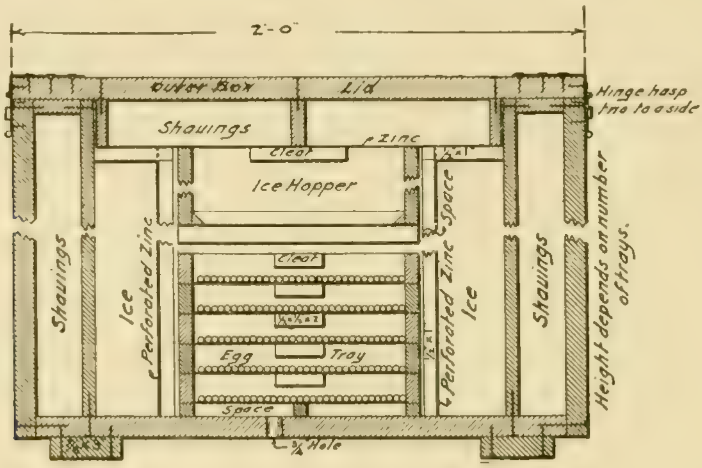

FIG. 10.—Argentine shipping case. Section.

Eggs selected for shipping should barely show the eye spots without the aid of a glass. In packing, a layer of damp moss is spread one-fourth of an inch deep as evenly as possible over the tray bottom, and upon this is placed a covering of mosquito net or bobbinet. The eggs are laid upon the netting one or two layers deep, spread to within one-half inch of the tray frame and covered with another piece of netting to keep them separate from the moss, which is sprinkled in a light layer over it, filling the tray. The netting is cut large enough to extend over the outer edges of the tray, so that the eggs may not be disturbed when a tray is lifted for examination.

On shipboard, as the greater part of the journey is made, the cases of eggs are kept in one of the fruit or cold storage rooms having a temperature of about 38° F. To this room the attendant has access, and it is his duty daily to moisten

the eggs by pouring through the ice hopper water of the same temperature as the eggs, 34° to 35°. The ice compartments are frequently replenished and the eggs are picked over whenever necessary.

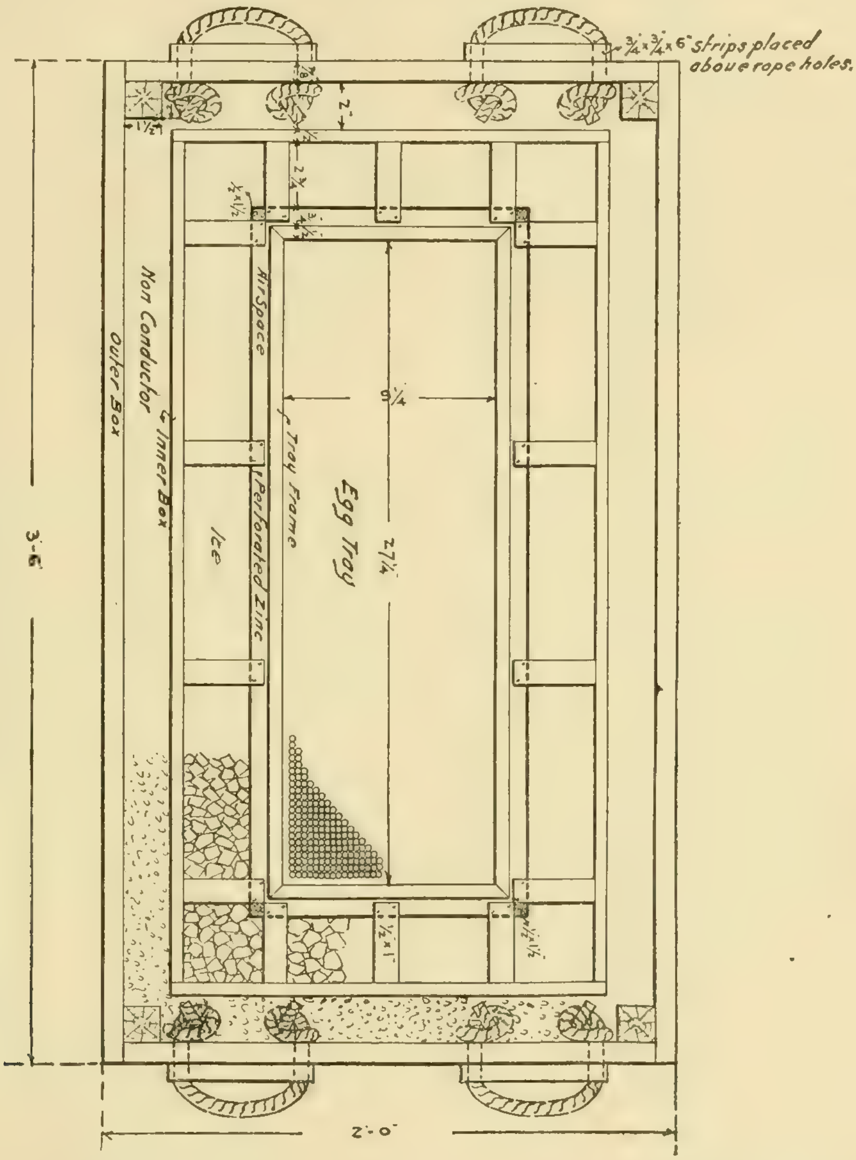

Fig. 11.—Argentine shipping case. Plan.

It will be seen that the method of caring for the eggs is not novel. The chief improvements in the case are to make it easy for the caretaker to tend the eggs in the crowded quarters of a ship's storage compartments and to facilitate handling each individual tray.

GERMAN-CHILE CASE.

Another case used on journeys in which the care of the eggs is the same as above described is the German-Chile case, so called by reason of having first been employed by German fish culturists in shipping trout eggs from Germany to the Chilean Government. It was brought to the attention of fish culturists in this country by Mr. E. A. Tulian, chief of the section of fish culture of the Argentine Government. In 1907 and 1908 this case, somewhat modified, was used by Mr. Tulian in transporting trout and salmon eggs from the United States to Argentina with better results than had been secured with any other form of case. Owing to the absence of moss directly on the eggs, the German-Chile case is especially adapted to the handling of rainbow trout eggs, the membrane of which is more delicate than that of any other species of the Salmonidæ. From the latest observations it is undoubtedly true that the ideal form of long-distance shipping case for all species, at least when accompanied by an attendant, is the one wherein no moss or other substance is placed directly on the eggs.

The German-Chile case is constructed on the same principles as the Argentine case above described. The case proper is built of selected lumber and is 29½ inches long, 20 inches wide, and 15 inches high, outside measurements. It is so similar in construction to the Argentine case that, aside from a general description, only the differences between the two will be pointed out.

The German-Chile case accommodates two stacks of trays 7¾ by 8½ inches, in a double-chambered compartment having walls of unperforated galvanized iron, which is strengthened by a heavy wire around the top edge. A removable metal partition separates the two stacks of trays. The compartment itself is made one-fourth inch larger each way than the tray frames, to allow for swelling and the binding twine which will be placed around the trays. Next to and surrounding the tray compartment is the ice, outside of which is the dry moss or other nonconductor, within wooden walls, the same as in the Argentine case, while resting upon the top of the trays and ice compartments is an ice hopper. For purposes of insulation the ice in the hopper is covered with a cushion filled with dry moss, oilcloth being placed between the cushion and the ice. The metal bottom of the hopper has perforations only over the trays, that the eggs may receive the benefit of all drip water. Small cleats are fixed at either end of the ice hopper to facilitate handling. Under the tray compartment and coextensive with it is a perforated wooden false bottom to the case, between which and the bottom proper is a 1-inch air space. A drain hole is provided in the bottom proper. The egg trays are made a trifle deeper than the diameter of the eggs; and the latter are placed on them a single layer deep without any

covering of moss. The tray frames are seven-eighths inch wide, and usually three-sixteenths inch to five-sixteenths inch thick, with a bottom either scrim

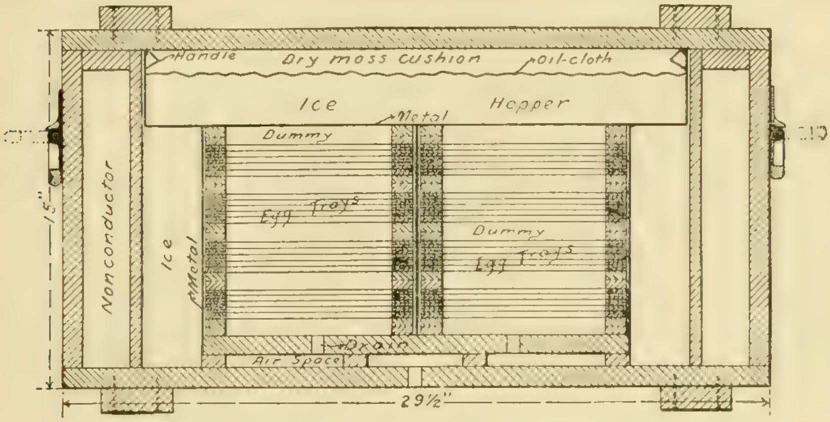

Fig. 12.—German-Chile shipping case. Longitudinal section.

or canton flannel. Instead of being made into one package for each chamber, the trays are bound together in fives, with strong twine for binding material, and alternating with each package are double-depth trays, or dummies, filled

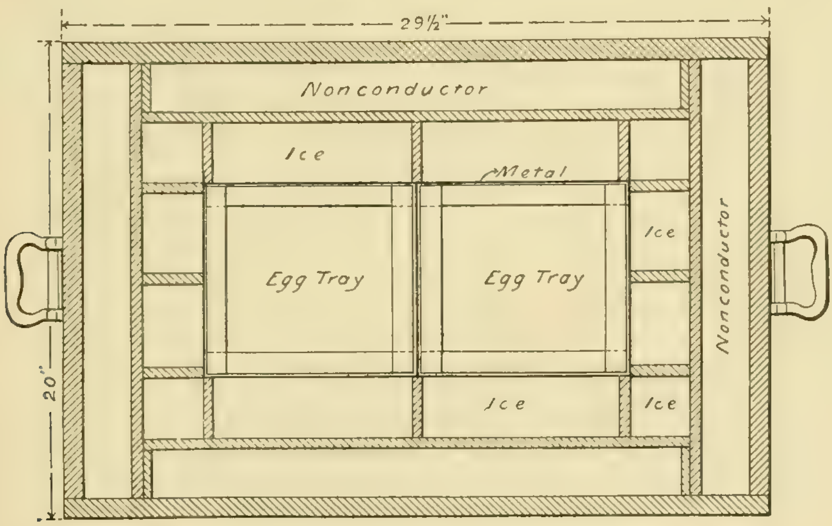

Fig. 13.—German-Chile shipping case. Plan.

with wet moss. One of these moss-filled trays is placed also in the bottom of each of the two tray chambers.

TRANSPORTATION OF FISH.

In distributing young fish from the hatcheries to the waters they are to stock, six special cars are employed. They are equipped with all necessary apparatus for the safe carriage of young and adult fishes and each is provided with a buffet and sleeping accommodations for a crew of five men. The cars are attached to passenger trains, and many of the railroad companies, appreciating the benefits arising from stocking waters along their lines, haul the cars gratis; others make special rates for cars and crew. When plants are made off the main railroad lines, the fish are carried in baggage cars in charge of members of the car crew.

In addition, distributions are made from many stations without the aid of the special cars, the station employees caring for the fish in baggage cars. For this service the railroad companies usually charge regular fare for the attendants but transport the fish and return the empty cans gratis.

Fry and young fish are usually transported in 10-gallon round-shouldered iron cans, tinned for fresh-water work and galvanized for marine work. With fresh water galvanized iron often proves toxic, and should never be used in the transportation of fresh-water fishes. On the cars it is possible to aerate the water in each fish can by air pumped through a reservoir, from which it is taken through lines of piping along the sides of the car. The piping is equipped with pet cocks, from which the air is carried to the cans in ⅝-inch rubber tubing and forced into the water through liberators made of porous wood, preferably the American linden (*Tilia americana*), placed in hard rubber holders. For best results these liberators must not be placed in the water until air pressure is on and must be removed when air pressure is stopped.

In putting up cod fry and fry of other marine fishes for shipment it is customary to have several quarts of water in the transportation cans and then carefully dip the fry from the hatching boxes, lowering the dipper to the water in the cans before emptying it. When the box is nearly empty the remaining fry are removed from it to a can by means of a siphon. When transported on a vessel having a conveniently arranged well, linen scrim is securely fastened over the top of each can containing fry and the cans are laid horizontally in the well, the top toward a perforated supply pipe through which water is pumped into the well, thus maintaining a constant current.

Lobster fry may be carried in scrim-walled containers, or boxes, suspended in the well of a vessel, the motion of the vessel and the constant circulation of water in the well keeping the fry in good condition and preventing their settling in a mass at the bottom. The boxes are made of a framework covered on the four sides and bottom with scrim, which allows a free circulation from all sides. Each box, 42 inches by 29 inches by 29 inches, will hold from 2,000,000 to

3,000,000 fry. It is customary to take from 12 to 15 cans of fry in addition to those taken in the well, the fry in the cans being the first planted.

On vessels having no wells, aeration for all species of the marine fry, including the lobsters, is accomplished by siphoning off and dipping the water freely, as will be described for whitefish, pike perch, etc. For tempering the water ice is suspended from the cover of the can in a cylinder.

Temperature is a most important consideration in the transportation of fishes, and owing to the different conditions under which they are hatched in the various localities, is a feature that requires skilled discretion on the part of the attendant. The general rule is to keep the temperature at least as low as that of the water from which the fish were taken, and lower if the species is not sensitive to changes.

The maximum number of fishes to be carried most advantageously in a 10-gallon can is another equally important question. The distance to be traveled partly prescribes this number, but must be considered also with reference to the temperature; and these factors, interdependent as they are, go to prevent the formulation of any hard and fast rule. In the following table, however, attempt is made to generalize by means of average conditions, and show the number of fishes of specified kind and size as ordinarily transported in a 10-gallon can. The cooler period of the year in which handled accounts for the lower temperature for fry of the trouts as compared with the higher temperature of fingerlings. It also accounts for the lower temperature for landlocked salmon fingerlings as compared with fry. Ordinarily if landlocked salmon, rainbow trout, and brook trout fry from the same source should be distributed in warm weather it would be desirable to reduce the water temperature for the brook trout considerably lower than for the other two species.

Number of Fishes of Given Kinds and Sizes to be Transported in a 10-Gallon Can under Average Conditions.

Species.	Fry.		Advanced fry.		Fingerlings no. 1.		Fingerlings no. 2.	
	Number.	Temperature.	Number.	Temperature.	Number.	Temperature.	Number.	Temperature.
		°F.		°F.		°F.		°F.
Large-mouth and small-mouth black bass	3,000	60	1,000	61	400	62	225	63
Rock bass, bream, and catfish					400	62	225	63
Brook trout	5,000	40	3,000	45	1,500	50	500	50
Blackspotted trout	5,000	48	3,000	48	1,500	48	500	50
Rainbow trout	5,000	48	1,500	50	1,200	53	500	55
Lake trout	4,000	40	3,000	42	1,500	44	500	50
Steelhead trout	2,000	45	1,000	48				
Landlocked salmon	2,000	48	1,000	48			400	44
Whitefish	30,000	38						
Pike perch	100,000	60						
Yellow perch	125,000	50					200	60
White perch	200,000	53						
Shad	30,000	68						
Cod	300,000	42						
Flatfish	1,000,000	43						
Pollock	400,000							
Lobster	100,000	58						

Number of Fishes of Given Kinds and Sizes to be Transported in a 10-Gallon Can under Average Conditions—Continued.

Species.	Fingerlings no. 3.		Fingerlings no. 4.		Fingerlings no. 5.		Fingerlings no. 6.	
	Number.	Temperature.	Number.	Temperature.	Number.	Temperature.	Number.	Temperature.
		° F.		° F.		° F.		° F.
Large-mouth and small-mouth black bass	150	63	100	62	50	61	30	61
Rock bass, bream, and catfish	150	63	100	62	50	61	30	61
Brook trout	250	51	125	52				
Rainbow trout	200	55	100	55	75	54		
Landlocked salmon	150	44	100	44				
Yellow perch	150	60	100	60				

Note.—The varying usage in the classification of young fish as to size has caused such confusion and difficulty that the Bureau has adopted uniform definitions, as follows:

Fry=fish up to the time the yolk sac is absorbed and feeding begins.

Advanced fry=fish from the end of the fry period until they have reached a length of 1 inch.

Fingerlings=fish between the length of 1 inch and the yearling stage, the various sizes to be designated as follows: No. 1, a fish 1 inch in length and up to 2 inches; no. 2, a fish 2 inches in length and up to 3 inches; no. 3, a fish 3 inches in length and up to 4 inches, etc.

Yearlings=fish that are 1 year old, but less than 2 years old from the date of hatching; these may be designated no. 1, no. 2, no. 3, etc., after the plan prescribed for fingerlings.

In the care of fish away from the air circulation of the cars, aeration is usually accomplished by the use of a long-handled dipper, and this method for 10 or 15 cans, which is the usual number handled by detached messengers, if energetically operated has no equal. Several forms of aerating devices have their good points, their use is permitted, and efforts are being made to improve upon the present methods of hand aeration in order to lighten the labors of the messengers, who not infrequently care for the fish for two or three days before they arrive at a destination.

For aeration in cans containing small fry, such as the shad, pike perch, white perch, yellow perch, and whitefish, it is customary to siphon a portion of the water into a pail (the head of the siphon being in a wire cage covered with cheese cloth), aerate it with a dipper, add ice to temper it if necessary, and then pour it back through a large funnel which reaches nearly to the bottom of the can, the lower part of the funnel for about 6 inches being made of perforated tin to break the force of the water. On short trips little, if any, aeration is necessary.

Cans holding the larger fry and young fish may be aerated by dipping the water up and pouring it back again from a height of 15 or 20 inches. When transportation is by water it is customary to renew the water in the cans en route instead of resorting to hand aeration. With fishes of the Salmonidæ family, ice may be placed directly in the water in the cans.

DISTRIBUTION AND PLANTING OF THE COMMERCIAL FISHES.

It being infeasible for various reasons to rear the young of the commercial fishes, practically all are planted as fry and the distributions are usually made by agents of the Bureau.

Fry of the marine species are often transferred to small boats in order to plant in shallow water or they are carried from the hatchery in launches. In such cases the cans are lowered into the water by two men and there slowly inverted. When planting from a vessel two lines are made fast to the can, one about the top and one about the bottom; by this means the can is lowered over the side and when partially submerged is emptied.

On the Great Lakes the distributions of lake trout, whitefish, and pike perch are usually made by means of steam vessels. In such instances the water in the cans is renewed as often as necessary by siphoning off a portion and replenishing directly from the lake. The manner of liberating the fish after the point of deposit has been reached varies in practice. In planting lake trout and whitefish the method employed by the superintendent of the Duluth, Minn., station is to pour the water and fry, one can at a time, into a large tub full of water, from which the water and fish are siphoned through a heavy 2-inch rubber hose attached to a pole or outrigger. Thus they are deposited in the lake about 8 feet from the side of the vessel, very close to if not beneath the surface of the lake, the speed of the vessel being slackened while the planting is in progress. As it is customary to transport the fry on passenger or package freight steamers, where they are necessarily stowed in a limited space and as close to one gangway as possible, the cans may be emptied into a tub sitting firmly on the deck more easily and expeditiously than they could be poured directly into the lake, and the element of danger to the men doing the work is avoided also.

The superintendent of the Northville station follows a somewhat similar procedure in planting lake trout, pike perch, and whitefish fry. If the deck of the vessel is near the water surface a piece of ordinary tin pipe is attached to a tub and arranged with elbows so as to bring the lower end near the surface of the lake. If the deck of the vessel is high above the water the tub is used with 15 or 20 feet of 2-inch fire hose instead of the tin pipe, a weight being attached to the lower end.

From the Put-in Bay station the fry are planted by pouring them over the sides of the vessel as it moves slowly along, and the superintendent of this station, from experiments he has made, believes this method preferable to the use of hose or tin conductor as just described.

None of the salmon stations on the Pacific coast is of sufficient capacity to hold more than 10 per cent of the fry until sac absorption, and in California a large portion of the product is distributed to hatcheries operated by the California Fish Commission. The portion distributed by the Bureau from the Baird station, however, is held until sac absorption. The method of distributing from Baird is as follows:

The inflow to a trough is shut off, the drain pipe removed, and the water and fry allowed to pass into a double receptacle consisting of a perforated bucket inside a regular 5-gallon spawn bucket, the inner container being about 1 inch less in diameter and raised an inch from the bottom by wooden blocks. This receptacle has been filled with water, to prevent injury to the fry as they are poured in, and the surplus water escapes through the perforations and over the rim of the outside bucket, leaving the fry in the center. If the trough is some distance from the floor a box is used to elevate the buckets to proper level, and any fry remaining in the trough after the passage of the water are brushed through the opening with a broad, flat paint brush. By this method the fry can be removed from a trough in two minutes with absolutely no loss. From the bucket the fry can be easily poured into a 10-gallon can, but frequently they are carried to the river (about 100 feet from the hatchery) and planted direct from the buckets. So far as possible the plants are made during flood water and always where there is a strong current. By this means few, if any, free swimmers are caught by the ever-present trout, as their natural tendency quickly to scatter is facilitated by swift water.

DISTRIBUTION OF GAME FISHES.

The Bureau does not as a rule attempt to plant the game fishes produced at its hatcheries, but consigns them to individuals, anglers' clubs, protective associations, etc., by whom they are used to stock both public and private waters. It is customary to deliver the fish free of charge to the applicants at the railroad stations nearest the point of deposit.

The number of fish allotted to individual applicants is, of course, largely determined by the supply available, which depends to great extent upon the difference in methods of hatching applicable to the different species. The area and character of the water to be stocked must also be considered, of course. Moreover, the same water area that would receive a million pike perch fry would perhaps be assigned no more than 200 or 300 black bass 3 or 4 inches long, or four to eight times that many if the bass are planted as fry. The explanation is in the fact that pike perch can be propagated by the hundred million, while black bass, hatched by other methods, or collected from overflowed lands, are pro-

duced only in comparatively small numbers. The Bureau does not attempt to assign any applicant more than a liberal brood stock of the basses or sunfishes. With brook trout, which are distributed both as fry and fingerlings, assignments of fry are twenty-five to fifty times larger than assignments of fingerlings 3 to 4 inches long.

Applicants for fish are advised by mail of the approximate date on which the fish will be shipped and later by wire of the hour on which they may be expected to arrive. The advance mail notice also contains the specific instructions for the care of the fish from the time of delivery until they are planted.

A NEW PRINCIPLE OF AQUICULTURE AND TRANSPORTATION OF LIVE FISHES

By A. D. Mead, Ph. D.
Member Rhode Island Commission of Inland Fisheries

Paper presented before the Fourth International Fishery Congress, held at Washington, U. S. A., September 22 to 26, 1908, and awarded the prize of two hundred dollars in gold offered by the United States Bureau of Fisheries for a report describing the most useful new and original principle, method, or apparatus to be employed in fish culture or in transporting live fishes

CONTENTS.

	Page.
Essential features and development of the method	761
Adaptation to fishes and other pelagic forms	763
Requirements	763
Requirements satisfied	764
Adaptability of the method	765
Apparatus	767
General description	767
Details of structure	768
Possibility of variation	772
Precautions	772
Tests of efficiency	773
General application of the method in aquiculture	779
Application in transportation of live fishes	780

FIG. 1.—Floating laboratory and rearing plant from the port side. The forward (left) house serves as a laboratory and the after one as the engine house and tool room. Most of the rearing cars are covered with white awnings.

FIG. 2.—General view of the plant from the outer rear corner. In foreground one of the cars shows the propeller shaft and faint indication of propeller blades in the water.

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ESSENTIAL FEATURES AND DEVELOPMENT OF THE METHOD.

The method and apparatus herein described as a novel and practical method of fish culture have gradually developed through eleven years of continuous experimentation at the marine station of the Rhode Island Commission of Inland Fisheries. It may be said, indeed, that the method and the station have developed together. The aim has been throughout to provide as simply as possible the essential features of the natural environment, biological and physical, for aquatic animals while kept in confinement, and to introduce as little as possible the unnatural features which are frequently considered necessary in artificial culture. Upon this principle there has been sought a feasible method of providing water agreeable to the particular species in regard to the various component salts, well aerated but not over aerated, having the proper temperature, density, and current, and containing appropriate food in available condition; while providing at the same time for the elimination of waste products of animal respiration, and avoiding the dangerous chemical and bacterial impurities almost invariably present where the water is passed through systems of piston pumps, closed conduits, and storage tanks, and is aerated by means of forced air.

The first step in the development of the method was a very direct and simple concession, namely, that of going to the ocean instead of trying to bring the ocean into a house on land. The floating laboratory and hatchery was therefore adopted as a feasible method of circumventing, if not surmounting, many difficulties.

During the first and second seasons of work it was clearly demonstrated that the starfish (*Asterias forbesii*) could be reared in the course of the summer (four months) from the larval stage to over 50 millimeters measured from mouth to tip of arm (nearly twice the length of sexually mature specimens captured in June, the breeding season, and therefore a year old), in cars of

appropriate shape floating in the water between the pontoons of the houseboat. In this case living food was supplied at first in the form of small barnacles which had set on boards, and later, as the starfishes grew larger, clams, oysters, and mussels were given them to eat. The conditions in these cars were completely adequate for the healthy life of these slow-moving animals, and were abnormal only in that the young starfishes were protected from their enemies (excepting always their cannibal brethren) and were better fed than they often are under natural conditions. In many cases where they were especially well fed they far outstripped in rapidity of growth individuals found along the shore. They throve splendidly and were perfectly healthy.

This way of raising starfishes may hardly be dignified by the term "method," and yet the better condition of these specimens as compared with those usually seen in an aquarium—even in an aquarium where many fishes live for a long time—is a striking fact. It suggests also that there is often something the matter with aquarium water which, whatever the cause, makes it unsuitable for the rearing of very sensitive animals.

At the floating laboratory, animals with the burrowing habit can also be kept confined and protected and under constant observation by simply putting them into a box of sand suspended in the water. Specimens of the soft-shell clam (*Mya arenaria*) may in this way be very successfully and rapidly reared, and they give every indication of being in a perfectly normal environment. Indeed, in our experiments, when they were kept just under the surface of the water and in the tidal current, they grew more rapidly than in the most favorable shore locality I have ever seen. In one experiment with clams ranging from 5 to 17 millimeters the increase in bulk during five weeks and two days was 1,861 per cent.

In the case of sessile animals like oysters, *Crepidula*, *Anomia*, *Molgula*, *Botryllus*, sea anemones, tubiculous worms, etc., and of those which spin a byssus, like the mussel, young clams, and pectens, it is only necessary to provide the proper surface for them to set on and protection from predatory animals. In case of the hatching of such eggs as those of the flatfish, *Menidia*, *Fundulus*, and the lobster, with which we have had experience in the course of our operations, it would seem that the term "hatching" could hardly be used in a transitive sense, for, if the eggs are provided simply with water of proper constitution, temperature, and conditions for respiration, the eggs inevitably hatch themselves. These nonpelagic eggs, in fact, belong to the same category as the sessile or slow moving animals and may be treated accordingly. The method of stripping and swirling lobster eggs has been given up with us and instead the ripe-berried hen-lobsters are allowed to crawl about in the rearing cars with the result that the eggs hatch most satisfactorily. Similarly the eggs of the flatfish (*Pseudopleuronectes*) were hatched with almost no loss by placing them on a

piece of scrim which formed the bottom of a box about 6 inches deep floated on the top of the water in a protected pool. The eggs of *Menidia* and *Fundulus* are hatched successfully by practically the same treatment.

ADAPTATION TO FISHES AND OTHER PELAGIC FORMS.

REQUIREMENTS.

In the development of the method of fish culture with which our station is identified the installation of a laboratory directly upon the water and the confining and rearing of animals in cars placed in the water marked the first step. For many animals of the types we have mentioned, the slow moving, or creeping, the burrowing, and the sessile animals, this is all that is necessary for rapid and healthy growth. For pelagic animals, however, like the young of most fishes and the larval forms of crustacea and other marine invertebrates, it is not sufficient. The very peculiarities of structure and instinct which adapt these creatures to their pelagic life make it difficult to confine them for a long time even in relatively large inclosures of the water in which they normally live.

One is baffled now by one peculiarity and now by another. The larvæ or fry are often strongly heliotropic, and in going toward or away from the light soon strike the boundary wall of their confine, and when they are numerous, as they must be in practical culture, die from the effects of crowding, if, indeed, they are spared to this fate by their cannibalistic comrades. Often in the blind struggle to go toward the light regardless of the boundary wall, they gradually work their way to the bottom and become entangled in débris or covered with silt.

If, for the sake of good circulation of water, the tidal current is allowed to pass through the car, as in the case of sessile or bottom-living forms, the pelagic fry are apt to be swept against one side, or to collect in eddies, with disastrous results. If, on the other hand, the current through the inclosure is not supplied, the water becomes stagnant and not well aerated, and since the time required to rear most animals to a considerable size is long, the stagnation under these circumstances is almost inevitable.

The minuteness of many larval animals constitutes a fourth difficulty, for perforations or meshes large enough to permit sufficient circulation frequently permit also the escape of the fry, while meshes too small for the fry to go through become clogged with silt and do not allow free circulation.

The fifth difficulty in the rearing of pelagic fry in inclosures of this kind depends upon the fact that normally they capture their prey "on the fly." A dilemma presents itself: If the fry are fed upon smaller animals or plants, these too must be pelagic, involving all the difficulties over again, while, if artificial food is used, there is no provision for keeping it in suspension, in which condition only would it be available.

REQUIREMENTS SATISFIED.

After the first step was taken and the excellent result of rearing bottom-living animals in native water was recognized, it seemed most desirable to follow up the advantage gained in the rearing of other forms by extending and developing the procedure so that it would be applicable to pelagic fry. Fortunately we were able to hit upon a method which solved at once all the main difficulties arising from the peculiarities of pelagic existence of larvæ and other free swimming animals. This method consists essentially of creating and maintaining within an inclosure of "native" water a gentle upward swirling current. It obviates the several difficulties which we have enumerated as peculiar to pelagic fry in the following ways:

It effectually prevents the crowding of the fry to one wall of the car, for the force of the current carries them round and round continuously, nor can they work their way to the bottom, for the current has an upward as well as a rotary direction. Even the cannibalistic propensities, which are so pronounced in the larval stages of lobsters and some other animals, are rendered innocuous to a great extent by the forced separation of the fry and are mitigated by the availability of other food.

The current being wholly internal, and its main component circular in its course, it does not force the fry strongly to one side nor allow them to remain in one place as does the tidal current passing through the inclosure. The pressure of the current against the sides varies, of course, with the rapidity with which the outside water is drawn into the car, with the extent of the area through which the water can pass out, and with the rapidity of the current. Since any or all of these factors can readily be controlled there is no difficulty in obtaining a proper adjustment of current for the requirements of particular cases.

Stagnation is prevented even when no new water is admitted from the outside, for the water in the car is constantly being turned over and the lower strata brought to the top and aerated. When, therefore, the water of a car of considerable size is kept cool by being sunk into the ocean and shaded from the sun and is continuously forced to the surface so as to be relieved of waste gases as well as recuperated with oxygen, there is comparatively little need of continuous or frequent renewal. It is at least reasonable to suppose that, in what we may call (after Birge) the "respiration" of a small inclosed body of water containing a considerable quantity of animal life, the elimination of the waste or toxic gases is necessary, and that aeration which is accomplished by forcing more air into the water only partially fulfills the requirements of respiration. The analogy with the physiological process of respiration would seem to be real. In case of small, very thin, flat animals, where the ratio of surface

to the bulk is large, respiration may be continuous and direct without special internal apparatus, and, likewise, shallow water with a large expanse of surface has been found by experiment to need no aeration in order to maintain animals alive for a long time. On the other hand, in bulky animals, the respiratory apparatus provides always for the elimination of gaseous products of metabolism as inevitably as it provides for the acquisition of oxygen. Therefore the bringing of the lower strata of water continuously to the surface fulfills two necessary requirements.

For keeping larval forms which are not exceedingly minute, windows covered with screens about 16 meshes to the inch in the bottom of the cars allowing for intake, and similar ones in the sides for the exit of water, are satisfactory. A much finer mesh can be used in this case than would ordinarily be practicable, because the water is drawn in through the bottom screens with considerable force by the upward tendency of the current. It is possible by means of a filter device, which will be described hereafter, to hold fry which would pass through even very fine screens.

The rotary upward current keeps the particles of food suspended in the water even when artificial food heavier than water is used. When, on the other hand, a pelagic live food is used, it is also, of course, readily available, because it is kept in motion and suspended. The important problem of the distribution of food for pelagic forms is solved by this method in a most satisfactory manner.

ADAPTABILITY OF THE METHOD.

Before describing the apparatus as at present installed at our station, where it is applied to the hatching and rearing of young fishes and invertebrates, a word should be said to indicate its general adaptability to various requirements. In any protected body of water, whether river, lake, pond, or in the ocean itself, the apparatus can be quickly and cheaply installed. For experimental work the containing cars may be small. Dr. V. E. Emmel, by use of this method, succeeded for the first time in the difficult task of making mutilated lobsters of the first stage live to regenerate their appendages. His apparatus consisted of an ordinary "paper" bucket provided with screens and the apparatus for keeping the water in motion. On the other extreme the units in our regular installation at Wickford are square boxes measuring 10 feet on a side and 4 feet in depth, with capacity approximately 12,000 liters (fig. 4, 5, 6, pl. XCI, XCII). The capacity of a plant of this sort is capable of unlimited extension by the addition of units. At present the plant at Wickford has a capacity of 24 units of the size mentioned. The method is capable of application to aquatic animals, fresh water or marine, varying in size from those literally microscopic to those of a foot or more in length. We do not

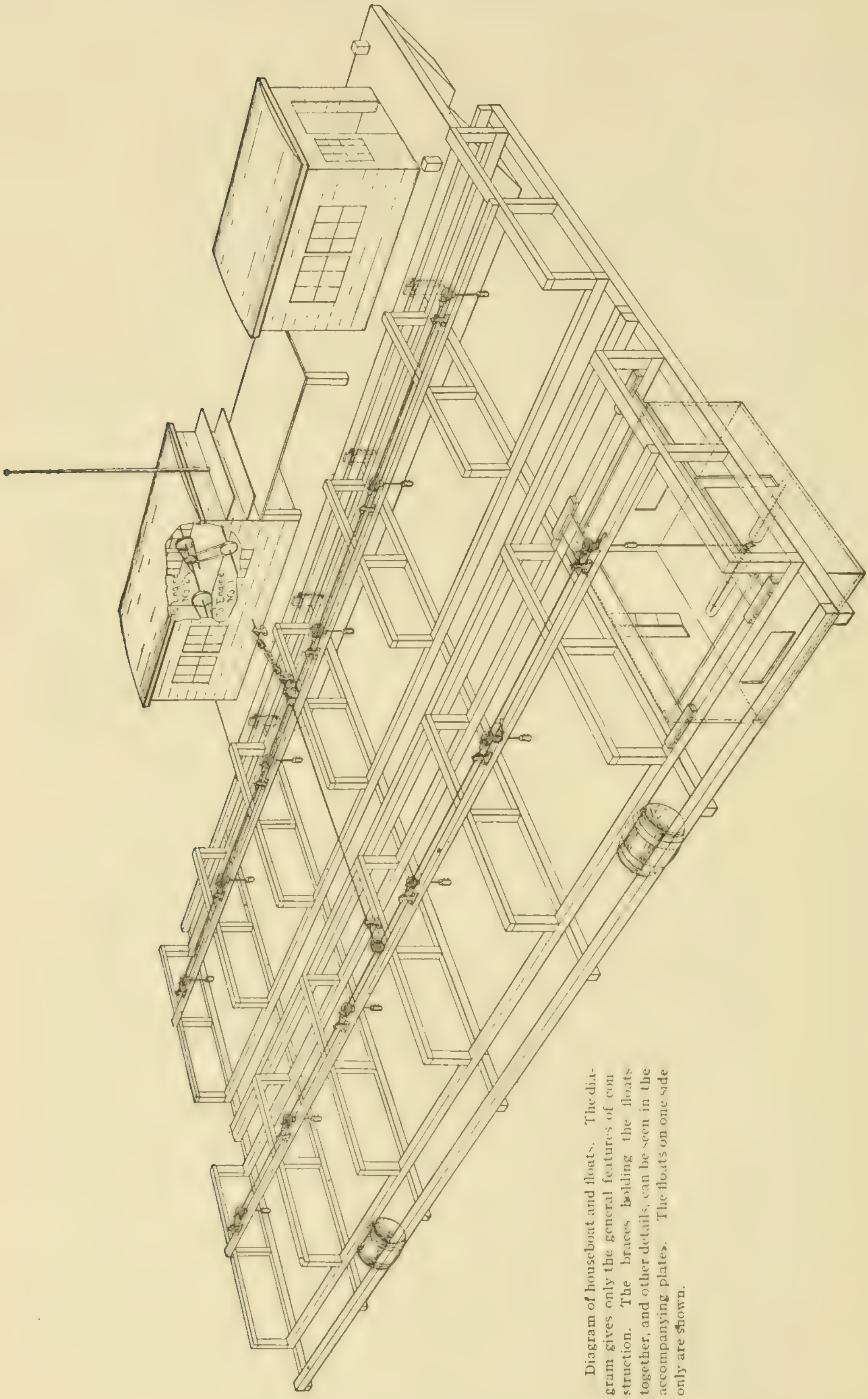

Diagram of houseboat and floats. The diagram gives only the general features of construction. The braces holding the floats together, and other details, can be seen in the accompanying plates. The floats on one side only are shown.

foresee that there are any strictly aquatic animals the requirements of whose young may not be fulfilled by means of this method.

We have developed and applied the method mainly in connection with the hatching and rearing of larval lobsters, but we may assert, without fear of contradiction by anyone familiar with the rearing of lobster fry, that we have done this not because of the comparative ease of rearing lobsters. In the case of all species of fishes which we have attempted to rear the problem is easier than in the case of lobsters.

APPARATUS.

GENERAL DESCRIPTION.

The apparatus as at present installed has proved capable of rearing the larval and young stages of fishes and of invertebrates belonging to several different groups. The main features are as follows: A houseboat consisting of two decked pontoons 4 by 4 feet square in section and 50 feet long held 8 feet apart, the intervening space decked and covered by two houses 10 by 10 feet square and 10 by 20 feet, respectively, flanked on either side by two floats attached to the houseboat and made of 6 by 6 inch spruce timbers bolted together and buoyed up by barrels. The spaces between the timbers of the floats are divided into areas 12 by 12 feet, to contain the hatching cars, and into alleyways about 2 feet wide, to contain the supporting barrels. (See diagram, p. 766, and fig. 1, 2, 3, pl. XC, XCI.)

The inclosures for confining the fry are in the form of 10-foot square boxes (fig. 5, pl. XCII) having two windows in the bottom and two windows in two sides, the windows screened, in the case of lobster fry and very small fishes, with fine-meshed woven bronze wire.

In each box or car a pair of propeller blades, adjustable to various angles, are horizontally placed, attached to a vertical shaft with proper bearings (fig. 4, pl. XCI; fig. 6, pl. XCII; fig. 18, pl. XCVIII). By the revolution of the propeller blades the water is kept in circular and upward motion (fig. 4). The propeller shaft carries at its top a gear which engages a similar one with half the number of teeth borne on a horizontal longitudinal driving shaft. The paddle shaft can, however, be instantly thrown out of gear by a lever (fig. 22, pl. C). The longitudinal shaft transmits the power to all the propellers in one float (fig. 2, 3, and diagram). It receives its power from a shaft running transversely across the float, the two shafts being connected by mitered gears (fig. 4). The transverse shaft of the float is connected to a similar one across the houseboat by a set of universal ball joints and an extensible shaft and sleeve device, invented for this particular purpose, which allows for several inches of variation in the length of the shafting system (fig. 17, pl. XCVIII). The transverse shaft on the houseboat runs through the side of the house and inside the

latter is connected with the engine by two sets of pulleys and belts which greatly reduce the speed (diagram, p. 766).

A small gasoline engine furnishes the power. The engine speed of 324 revolutions per minute is reduced to about 36 revolutions per minute in the transverse shafting; then, by gears, to 18 revolutions in the longitudinal shafting, and to 9 revolutions per minute for the propeller blades within the boxes.

Four horizontal driving shafts running lengthwise of the float are each 63½ feet long. The transverse shafts connecting these back to the engine have a combined length of 43 feet. The four large floats are only skeletons in structure. Both they and the houseboat to which they are attached float upon the water and are subjected to considerable motion from the waves and from the swells of passing vessels. A too rigid construction, therefore, is not permissible. Indeed, a friend of the station who is familiar with mechanical construction facetiously observed that any reputable engineer to whom we might submit the plans of our apparatus would without hesitation assert that it probably would not work. However, it runs continuously with hardly an hour of interruption for three or four months at a time.

Several devices have been adopted which together make sufficient allowance for the inevitable rocking movement of the floats and for the warping of the light timbers, viz, comparatively light shafting (1 inch), which in long pieces is flexible; adjustable hangers; large-tooth cast gears; and the sliding shaft and universal joint which has been mentioned. No trouble with the running of the apparatus has ever arisen from the motion of the water, though the latter is sometimes strong enough to break out the screen windows.

DETAILS OF STRUCTURE.

Houseboat.—A brief description of the houseboat with its materials and dimensions is as follows: Two pontoons 52 feet long, 4 feet wide, and 4 feet deep, of 3-inch hard pine calked, completely decked with 2-inch hard pine calked; each pontoon with 3 bulkheads and 4 water-tight compartments accessible by hatches, painted all over, copper paint below water line; pontoons placed 8 feet apart securely fastened by crossbeams and heavy knees at each end; houses 10 by 10 feet near each end of the boat, with floors of 2-inch hard pine, roofs, sides, doors, shelves, closets, of North Carolina pine, painted outside, natural-wood finish inside; roof of house 7 feet from floor and having a slight crown, covered with canvas and painted. An annex to the house (fig. 2, pl. XC) on one end, made of lighter material and of the same dimensions, has been added to give additional space for the engines and tools.

Floats.—The four side floats, so-called, are merely skeleton rafts, buoyed with barrels, whose construction may be seen in the diagram and on plates

XCI and XCII. Pieces of 6 by 6 inch timbers, spliced together if necessary, are bolted together to form a rectangle 19 by 75½ feet. Parallel with the long sides and 2¼ feet inside are similar timbers, running the whole length of the raft. This makes an alleyway on each side for the supporting of barrels, and the spaces between the barrels are available for small rearing boxes used in preliminary experiments. Across the inner long timbers are placed 6 by 6 inch beams at intervals of 12 feet, dividing the whole raft into six compartments 12 by 12 feet square for the reception of the rearing cars. Except for occasional spaces this completes the lower part of the raft.

Upon these beams short vertical pieces are set at the corners of the car pools to form a rest for the seven upper crossbeams which run parallel with the lower ones (p. 766, and fig. 3, 4, pl. XCI). These upper crossbeams of 4 by 6 inch stock support a longitudinal shaft beam, also 4 by 6 inches, which runs the whole length of the float through the middle and upon which are fastened the shaft hangers.

The two floats on either side of the houseboat are fastened rigidly together with bolted timbers. The inside floats are attached to the houseboat by means of D irons and eyebolts to allow about a foot of up-and-down motion. The floats are built comparatively light and of cheap wood, in view of possible future change of plan as a result of experience.

Rearing boxes.—The rearing boxes are square, made of ⅞-inch spruce tongued and grooved boards, nailed to a 2 by 3 inch frame with galvanized nails. The inside dimensions are 10 by 10 by 4 feet. The angles between adjacent sides and between the bottom and sides are truncated by boards 9 inches wide and beveled on the edges (fig. 6, pl. XCII; fig. 13, pl. XCVI). The vertical corner frame pieces are left projecting above the top of the box about 2 inches, to serve as corner posts for fastening the box in place. Ring bolts are put into the four lower inside corners of the box for use in raising the box for cleaning.

Window cases 9 by 36 inches are placed on two opposite sides of the box to receive the movable window frames (fig. 6, pl. XCII; fig. 10, pl. XCIV). Two similar removable window frames 22 inches square are placed in the bottom about 3 feet from the diagonally opposite corners of the box (fig. 6). The size of the mesh in these screen windows varies, according to the size of the fry under experiment, from 16 to 2 meshes to the inch. The material is usually woven bronze or copper wire or galvanized "iron."

In the middle of both sides of the box not having windows a broad slot is cut from the top to within about 8 inches from the bottom. It allows the box to be raised above the water, even though the shaft beam is low (fig. 5, 6, pl. XCII). When the box is down the doors (seen in fig. 9, pl. XCIV), which are fastened on the side of the slot referred to, are fastened shut by strong outside buttons.

It should be said here that this construction was adopted to save rebuilding the floats which had formerly held canvas bags, in which case the low shaft beam was not in the way. In the case of new construction, the shaft beams should be high enough to escape the box when the latter is raised out of the water (fig. 5, pl. XCII).

The boxes are buoyant and have to be forced down into position, where they are held fast by two planks across the top at the end of the box (fig. 4, pl. XCI). The planks are mortised into the corner posts before referred to, so as to prevent lateral movement, and are fastened down to the beams of the float by heavy adjustable cleats secured by bolts (fig. 4, pl. XCI; fig. 9, 10, pl. XCIV). The boxes are painted inside and out.

When a box is to be raised, the cleats are loosened, the planks removed, and ropes from the drums of a transportable windlass are hooked into the ring-bolts of the bottom corners (fig. 9 to 12). The doors are then opened and the hand windlass put into operation. One man has raised a box alone in fifteen minutes, and two men in five minutes. These boxes, the windlass, and many other things were designed and constructed by the superintendent, Mr. E. W. Barnes.

Propellers.—The size and shape of propeller blades found to be most satisfactory vary according to the requirements of different fry. The form of those most used for lobster fry is shown in figures 6, plate XCII; 8, plate XCIII; and 18, plate XCVIII. They consist of two wooden blades, each 4 feet 2 inches long and 8 inches wide at the base, tapered to 5 inches at the apex, and painted all over. Along the middle line the thickness is about 1¼ inches, but from this to either edge is a long bevel which leaves about ½ inch at the edge (fig. 8). Each blade is fastened with iron straps to a piece of galvanized gas pipe, which is screwed into a four-way cross coupling (fig. 18). The latter admits also the vertical gas-pipe shaft running upward toward the gears and a short vertical steel shaft below which sets into a socket consisting of a short piece of large gas pipe fastened to the bottom of the car by a flange. This serves as a lower bearing or guard to the propeller shaft (fig. 18).

The upper part of the propeller shaft is continued by means of couplings through the longitudinal shaft beam and carries a mitered gear at the top (fig. 14, pl. XCVI). In order easily to disconnect and take out the propeller a heavy iron sleeve coupling is inserted into the propeller shaft. The two pieces of the latter are held into the sleeve coupling by set screws (fig. 19, pl. XCIX). As the set screws would be too heavy for galvanized piping, the lower part of the propeller shaft is continued upward by means of a piece of ordinary cold-rolled steel shafting (fig. 19). This is more easily shown in the figures than described.

Driving shafts and gears.—The gear on the top of the vertical propeller shaft engages a similar gear with half the number of teeth on the longitudinal driving

shaft (fig. 21, 22, pl. c). The latter is supported above the shaft beam by adjustable hangers. All the gears are cast instead of cut and have large teeth (fig. 20, 21, 22). For our purposes they are probably more satisfactory, and are certainly much cheaper, than cut gears. A nice adjustment is not necessary, and the speed of all the shafting is low, being 36 to 18 revolutions for the horizontal shafts and 9 for that of the propeller.

The longitudinal driving shaft connects by means of mitered gears to a transverse shaft running back toward the houseboat and engine (diagram, p. 766; fig. 4, pl. XCI; fig. 20, pl. XCIX). Between this and the transverse shaft of the houseboat is a pair of ball joints of the common type and the peculiar extension device referred to before (fig. 3, pl. XCI; fig. 17, pl. XCVIII). The latter consists of a sleeve made of two heavy castings fitting loosely over two pieces of square shafting. The two sleeve castings are provided with flanges and are held together by screws, and, to avoid their accidentally slipping off into the water, one end is made fast to the shaft with set screws. Several holes are bored through the sleeve for convenience in oiling. This device allows the square shafting to slide back and forth in the sleeve easily and it has the advantage of being very cheap. It is also very strong, because the shaft has a bearing on the sleeve on all four of its surfaces.

Shafting, pulleys, and engine on houseboat.—The transverse shaft on the houseboat connects with that on both pairs of side floats in the manner described, and is itself connected with the engine within the house by two sets of ordinary pulleys and belt drives in which the speed of the engine is greatly reduced. Two engines are set up ready to connect with the shaft, so that if either one gives out the other may be used. The engines are 2½ to 3 horsepower Fairbanks-Morse vertical type of gasoline explosion engines, and have proved exceedingly satisfactory.

Boxes with filters for holding minute larvæ.—As a modification of the usual form of box or car, to be used for rearing larvæ so small that they would go through any screen with meshes large enough to permit an adequate renewal of water, the following has been adopted: The ordinary boxes are carefully calked in all the seams, and their windows, save one of those in the bottom, are covered with canvas. A gravel and sand filter, made by putting about 4 inches of gravel and sand into a shallow box with wooden sides and heavy galvanized ¼-inch mesh wire in the bottom, is placed over the other bottom window (fig. 21, pl. c). When the car is in place, an old-fashioned bucket chain is rigged on the longitudinal shaft, and the water is thus continually lifted and poured into the hatching box through a short trough. The buckets are painted with asphalt inside and the trough is lined with canvas to prevent contamination of the water from contact with metal or wood. The new water is added, therefore, at the top of the box gradually—about 3½ gallons per minute (fig. 14, pl. XCVI; fig. 15, 16, pl. XCVII).

The amount of water passing through the bottom of the filter does not create an appreciable outward current, and, at any rate, the fry are held above the bottom by the upward trend of the current created by the propellers. Two or three cars of this type have been operated for periods of four to ten weeks at a time. Several varieties of very young fishes and larval invertebrates have been reared with highly satisfactory results. Among the many hundreds or thousands of animals only three or four dead specimens of any kind have been observed.

Canvas lining for boxes.—A further modification of this method has been adopted in order to prevent the escape of certain very small animals like crabs, which seek out and crawl into very narrow cracks in the wood. It consists of putting into the box a large canvas bag as a sort of lining and arranging the filter pump as usual (fig. 16, pl. XCVII). This apparatus has also proved satisfactory.

POSSIBILITY OF VARIATION.

So detailed a description of the apparatus as at present installed and in use might without a further word leave the impression that this apparatus alone fulfills the requirements of this general method of fish culture. On the contrary, there is hardly a feature of the whole outfit that has not been represented, at one time or another during our experiments, by other materials or other forms. The present boxes, for example, have replaced bags of canvas and of scrim and bobbinet, not because the latter failed to give good results, but because they were less durable and otherwise objectionable. Three forms of power transmission have been operated successfully during the development of the plant. It is obvious that the gasoline engine might under other circumstances properly give place to a different kind of motive power, such as steam or hot-air engines or electric, spring, weight, or water motors. For use in small experiments weight or spring motors, properly governed for speed, have much to recommend them, for individual cars could be independently operated in various localities without the inevitable expense and annoyances of running the engine and the apparatus for power transmission.

PRECAUTIONS.

There are, moreover, precautions to be taken in the construction of the cars and other devices. New wood, especially pine, and certain metals, particularly copper and galvanized iron, which are frequently used as screens, are apt to injure, and often prove fatal to young animals even when under other circumstances the circulation through the car would be ample. A very striking instance of the effect of small quantities of copper and zinc-plated screening was furnished in an experiment made a year ago at our station by Dr. V. E.

Emmel in rearing fourth-stage lobsters to the fifth stage.[a] Ninety fourth-stage lobsters were put separately into glass jars, one lobster into each jar, and the whole crate of jars submerged in the water about 2 feet below the surface. A screen of woven copper wire was placed over the wide mouth of each jar to keep the lobsters from escaping. All these lobsters were found dead twelve hours later. Galvanized copper wire screen was then substituted in a new experiment and in twenty-four hours the whole lot were dead. Finally a cloth screen of bobbinet was used, and out of 75 lobsters which were fed, only 1 died before moulting into the fifth stage. Of 15 which were not fed 4 died at the end of a month. These difficulties, if recognized, may in most cases easily be overcome.

TESTS OF EFFICIENCY.

The method and apparatus which have been herein described have been developed, as we have said, mainly in connection with the rearing of lobsters through their pelagic larval stages. But as proficiency in this work has increased we have come to realize that the method is equally well adapted to the rearing of a great variety of fishes and aquatic invertebrates.

Hatching and rearing lobsters.—While the hatching of lobster eggs by this method presents no difficulties, and young lobsterlings, after reaching the fourth stage, can also be cared for without the use of special appliances, the larval lobsters, on the other hand, during the three free swimming stages of two or three weeks' duration, seem to incarnate nearly all the perverse and intractable characteristics which, from the view point of fish culture, are difficult to deal with. They are pelagic and are safe only when floating, yet in confinement they persistently tend to go to the sides and bottom of the inclosure. They are comparatively slow of movement and weak in their instincts of self-preservation and of seeking food, yet their most distressing characteristic is cannibalism. A method of artificial culture, therefore, which will successfully cope with the various difficulties involved in the rearing of larval lobsters might, *a priori*, be expected to answer the requirements of the culture of fishes, few of which, perhaps, offer so many difficulties. While the report on the special method of rearing lobsters is given in another paper, it may here be said, as indicating the general efficiency of the plant, that during the months of June and July and the first few days in August of this year we hatched and reared through their successive larval stages more than 320,000 lobsters (counted) by means of the apparatus as above described.

Fishes incidentally reared.—While the apparatus was occupied with the rearing of lobsters, time and car space were not available for experiments on the rearing of fishes, but incidentally it was demonstrated that the young of many fishes would thrive and grow in the cars. Upon raising cars which had been

[a] Report of Rhode Island Commissioners of Inland Fisheries for 1907, p. 104.

down for two or three weeks there were nearly always found in them a considerable number of small fishes of various species. Since all the water of the car must in these cases have entered through the screen windows of $\frac{1}{16}$ inch mesh, the fishes must have come in when they were very small. The following is an incomplete list of these fishes found in the cars.[a] It should also be mentioned that among these fishes and the other young specimens placed in the cars there was no evidence of illness or mortality.

Species.	Size.	Dates.	Species.	Size.	Dates
	Mm.			*Mm.*	
Mummichog (*Fundulus* sp.)	5–25	Throughout season of 1907 and 1908.	Puffer (*Spheroides maculata*).	4	(?) 1908.
Silversides (*Menidia* sp.)	4–21	June 27 to July 8, 1908.		3.5	July 9, 1908.
Hake (*Urophycis* sp.)	28	July 26, 1907.		18	Aug. 3, 1908.
Pipefish (*Siphostoma fuscum*)	15	July 6, 1908.	Flatfish (*Pseudopleuronectes americanus*).	10–21	From about June 15 to about July 1, 1908, from 10 to 50 were found in every car when raised
	30	Aug. 6, 1908.			
	114	Aug. 7, 1908.			
	77	Do.			
	144	Aug. 8, 1908.	Tautog (*Tautoga onitis*)	3.2	July 8, 1908.
	66	Aug. 21, 1908.		4.8	July 9, 1908.
	73	Do.		20	July 25, 1908.
Kingfish (*Menticirrhus saxatilis*).	41	Aug. 4, 1908.		11	July 28, 1908.
				20, 18	Aug. 3, 1908.
Squeteague (*Cynoscion regalis*).	4.2	July 23, 1908.		20, 24	Aug. 4, 1908.
	19	July 30, 1908.		12.5	Aug. 7, 1908.
	12.5	July 28, 1907.		8, 9	Aug. 9, 1908.
	6.5	Do.		23, 25	Aug. 10, 1908.
	25	Aug. 8, 1907.		21, 41	Aug. 11, 1908.
	18	Do.		8	July 28, 1907.
	20	Aug. 9, 1907.		5.5	July 25, 1907.
	29	Aug. 13, 1907.			
	31	Do.			
	37	Aug. 26, 1907.			

From July 6 to the last of August, 1908, small anchovies (*Stolephorus mitchelli*) continually entered the cars through the fine screens. In many instances hundreds of them, from 2 to 20 millimeters long, were found in these cars. In August several cars were fitted out with coarse screens, one-fourth

[a] From data collected by H. C. Tracy.

inch mesh, and several thousands of anchovies entered one of the cars in a single night. Within the cars they lived and grew. Great numbers of very small specimens between 2 and 10 millimeters in length were taken in July. Mr. Tracy points out a fact of particular significance, namely, that in the tight filter cars many specimens from 2 millimeters to 8 millimeters were found which must have been dipped up by the chain of buckets as eggs or as very small fry, since the fry of 10 millimeters are so quick and wary that they would hardly be caught in this way. There is no doubt whatever that the young anchovies of all sizes thrive perfectly well in the cars provided with screens, and also in the filter cars, and it is more than probable that the eggs of this species frequently hatched in the cars.

About 20 anchovies placed in one of the filter cars on July 28, 1908, were doing well at the date of writing (September 19, 1908), and showed a very considerable growth.

Hatching and rearing fishes.—Near the end of the season for rearing lobsters, during the latter part of July, when the pressure of other work was relieved, some of the large cars were reserved for definite experiments to test the practicability of the method and apparatus as applied to the hatching and rearing of fishes. Unfortunately at this time of the year there were comparatively few fishes whose eggs we could obtain, and we were unable, therefore, to exercise much choice in our material.

On July 17 a quantity of eggs of the "silverside" (*Menidia*) were obtained, and, after being fertilized, were put into a car with the filter and bucket-chain rigged as already described. A short-bladed paddle was used like that in figure 22. This was hung about 2 feet from the bottom, the lower bearing being dispensed with.

The egg masses were teased apart into small clusters and placed on a piece of cloth mosquito netting which was tacked to a piece of soaked wood, so as to form a bag, and suspended in the water. The bag thus formed was held extended and kept from collapsing by a coiled piece of insulated electric wire on the inside. (Practically the same method has been used very successfully in the hatching of the flatfish, *Pseudopleuronectes.*) The eggs hatched in about ten days with apparently no mortality. The young fishes readily escaped through the netting and seemed to thrive perfectly well in the car, where they were kept until August 21, when they were transferred to another similar car, which, however, had a canvas lining. Here they have continued to live until the date of writing (September 19, 1908). There has been no evidence of mortality of any kind during the experiment, although little attention has been given to the feeding, and the fry have had to depend upon the living pelagic food which entered with the water from the chain of buckets.

From the time of hatching to the transference of the fry to another car specimens were taken out daily and preserved. The average daily measurements are here given:

	Mm.		Mm.		Mm.
July 26	3.85	August 4	7.90	August 11	8.22
July 27	4.86	August 5	7.70	August 12	8.80
July 29	5.82	August 6	7.76	August 13	9.20
July 31	6.21	August 7	8.32	August 14	8.77
August 1	6.90	August 8	8.00	August 15	9.30
August 2	7.19	August 9	7.98		
August 3	7.68	August 10	8.23		

On the afternoon of July 27 a portion of the eggs which had remained unhatched in the experiment thus described were transferred to another similarly rigged rearing car (known as S 4), and these eggs hatched within the next day or two. The measurements of specimens taken daily from this new car compare in an interesting way with those given in the previous table. Although they came from the same batch of eggs, and differed only in being slightly younger, they grew more rapidly than the first lot and soon so far outstripped those in the original car that the difference was noticeable upon casual observation.

This difference was doubtless due to the fact that the second lot had more to eat because there were fewer specimens in the car, for, as we have said, the fry had to depend for their food upon the pelagic fauna. By towing in these cars with a small bolting cloth net the absence of copepods and larval animals was conspicuous, especially when compared with the towings taken from a neighboring control car which was in all respects similarly conditioned except that it supported no young fishes. In the latter the pelagic life was abundant. It was evident that the swarm of young fry used up the supply of pelagic food as fast as it came into the car.

The following table gives the daily average length of specimens of *Menidia* in this second experiment:

	Mm.		Mm.		Mm.
July 27	4.52	August 3	7.76	August 10	10.04
July 28	4.91	August 4	8.72	August 11	10.34
July 29	5.04	August 5	9.00	August 12	10.12
July 30	6.06	August 6	9.98	August 13	10.74
July 31	5.51	August 7	9.82	August 14	10.21
August 1	6.57	August 8	10.02	August 15	11.72
August 2	7.58	August 9	9.25	August 17	10.26

The regular measurements were discontinued after this date. On September 8 the average measurement was 14.83 millimeters and on September 14, 14.45 millimeters. In all of these measurements different groups of individuals were caught up, and the averages, therefore, seem to show a decrease in size rather than an increase when there is not considerable rapidity of growth.

A few eggs of *Fundulus heteroclitus* were fertilized on July 27 and were placed in the original filter car. They were floated near the surface in a shallow bag of netting somewhat similar to that described in the case of *Menidia*. The eggs hatched on August 5 and 6 and the fry all lived in healthy condition until they were taken out at intervals and preserved. The daily averages of length for the first ten days are as follows:

	Mm.		Mm.		Mm.
August 5	4.92	August 9	5.56	August 13	5.98
August 6	5.07	August 10	5.37	August 14	6.25
August 7	5.40	August 11	5.88	August 15	6.30
August 8	5.35	August 12	5.92		

Specimens of this lot have continued to live in one of the cars until the date of writing (September 19).

On July 17, 56 young toadfish, measuring from 15 to 17 millimeters, which had been raised from the eggs in a small car, were transferred to the original filter car. At more or less irregular intervals during the next four or five weeks specimens were taken out and measured. The following table of individual and average measurements indicates the rate of their growth:[a]

	Mm.		Mm.
July 17 (56 specimens)	15.0–17.0	August 11	26.0
July 30	19.0	August 14	26.5
July 31	22.5	August 21	[b] 19.0–33.7
August 1	18.7, 22.0		

In order to test these cars with as many kinds of fishes as possible, we introduced the young of some other species in lieu of fish eggs, which could not be obtained in great variety at this season of the year. On July 17 a lot of pipefish taken from the brood pouch of a male were put directly into the original filter car. The individuals appeared to be of practically equal length and measured 10 millimeters. They apparently all lived and, like the other specimens in the cars, continued to thrive, showing no sign of disease, until they were taken out, on August 21.

The following data show the rate of growth as indicated by the average sizes at the end of irregular periods. No food was given to them except that which came in with the water by means of the chain of buckets.

	Mm.		Mm.		Mm.
July 17	10.0	July 30	44.0	August 15	67.2
July 18	11.4	July 31	46.1	August 20	69.4
July 20	21.8	August 2	52.6	September 8	[c] 71.3
July 23	24.5	August 6	61.6	September 14	[c] 70.0
July 25	27.5	August 8	58.6		
July 27	26.5	August 11	67.4		

[a] I am indebted for these measurements to Mr. H. C. Tracy.

[b] Average, 30.21 mm. Fifty-four specimens out of 56 put into the car were recovered.

[c] Measurements taken after transference to new car.

On August 21 the remaining specimens were transferred to another filter car with canvas lining, where they remained alive and well up to September 19.

On July 21 another pipefish was caught with a brood pouch full of young which measured 10 millimeters. These young were placed, together with the second lot of *Menidia*, in a filter car rigged with a chain of buckets like the original one. These specimens lived and thrived equally well. No food was given them except on one or two occasions. The data of growth are as follows:

	Mm		Mm.		Mm.
July 23	10.7	August 6	37.8	September 8	59.0
July 27	19.0	August 8	41.8	September 14	62.8
July 30	24.0	August 11	41.9		
August 3	31.4	August 15	45.2		

On August 8 and 10 a number of young bluefish were caught in the seine and were placed in one of the rearing cars which had been provided with coarse window screens of ¼ inch mesh. When put into the car there were already present in the water several thousand young anchovies, about 20 to 25 millimeters in length. These the bluefish ate during the first day. On several occasions a few *Menidia* and *Fundulus* were given them to eat. On August 12 they were given as much raw meat as they could eat, and this they devoured ravenously. They were fed on meat again on August 15 and on *Menidia* two days later. The average size of these bluefish on August 18, about ten days after they were put into the car, was 140.8 millimeters, an average increase of about 10 millimeters. On September 1 they were measured again, having been fed meantime on several occasions with *Menidia*, *Fundulus*, and other small fishes. The average length on this date, September 1, was 174 millimeters. This measurement and the two which follow were taken from the nose to the end of the fin rays, whereas the previous measurements were taken from the nose to the base of the fin rays. Between September 1 and September 8 the specimens were not fed. On September 8 they measured 175.1 millimeters, showing an increase during seven days of 1.1 millimeters.

On September 8 a quantity of live fishes was put into the car to serve as food for the bluefish, and during the next seven days the bluefish showed an average growth of about 10 millimeters, the average length being 184.3 millimeters.

The filter cars which have been described, and in which the previously mentioned eggs and young fishes were kept alive, have also proved themselves capable of maintaining a considerable variety of other fishes and invertebrates, among which are the following: Tautog, flatfish, anchovy, oysters (both old and young), scallops, anomia, crabs, barnacles, polyzoans, *Botryllus*, *Nereis* larvæ, etc.

Crabs and scallops.—On August 2, 1908, a very large number of zoeæ and megalops of the oyster crab were found floating at the surface of the water. A

considerable number were caught with a net and transferred to one of the filter cars, in which they have remained ever since. On September 19 their average measurements were, length $85\frac{5}{8}$ millimeters and breadth $101\frac{1}{4}$ millimeters (Mr. Sullivan).

On August 3, 13 scallops, measuring between 45 and 65 millimeters in length, were placed in the second filter car after having a deep notch filed in the shell so that the rate of their growth could be determined accurately. On September 18, 11 of these specimens were taken out of the car and were in excellent condition. The notch and the zone of new growth indicated precisely the size and shape of the shell when the scallop was placed in the box. The increase in length was about 20 per cent. The following table gives the measurements of these specimens:

Length, Aug. 3.	Length, Sept. 18.	Length, Aug. 3.	Length, Sept. 18.
Mm.	*Mm.*	*Mm.*	*Mm.*
50	60	51	60
44	55	52	64
47	60	46	56
60	68	52	62
45	55		

GENERAL APPLICATION OF THE METHOD IN AQUICULTURE.

There are two great problems in the general question of fish culture to the solution of which the method herein described contributes:

First, to the problem of hatching and rearing to an optimum size for liberation quantities of fishes of economic value for the direct purpose of stocking the waters. The comparative ease of hatching eggs of most fishes has resulted in the establishment of many prolific hatcheries; on the other hand, the number of establishments capable of rearing young fishes and the number of species so reared in confinement are few. A method of culture, therefore, which is capable not only of hatching but of rearing large numbers of fishes of widely different species marks, we hope, a new step in fish culture.

The second general problem is the ascertainment of the appearance, habits, requirements, and rate of growth of economically important fishes in their early stages of post-embryonic development. As contrasted with the vast amount of investigation of the embryonic stages of development, which has been facilitated by the abundance of readily available material in the form of eggs of all stages, the data relating to the post-embryonic development are almost entirely lacking. Even the identification of the young of many food fishes abundant in their spawning season is at present impossible. A method by

which eggs of widely different species may be hatched and reared and by which the unidentified fry caught at large may be reared under observation will be able, we hope, to furnish the necessary material for the solution of this general problem.

APPLICATION IN TRANSPORTATION OF LIVE FISHES.

In our opinion the essential principle upon which this method of fish culture is based will be found of value in solving the problem of the transportation of live fishes and, moreover, the method and even a portion of the apparatus can be modified and adapted so as to carry this principle into effect. The principle is, briefly, to provide at the start native "unmodified" water; to maintain a proper temperature and density, and in some cases current; to secure the continuous "respiration" of the water, including the egress of waste gases of the metabolism of contained fishes and often of bacteria as well as the access of oxygen, and to avoid contact with injurious metallic substances.

To carry into effect this principle we propose the following method: To use for transportation an iron tank enameled on the inside with a vitreous substance in order to prevent contact of the water with the metal; to use only water dipped from the water in which the animals have been living, in order to insure its proper constitution; to surround the tank with a jacket into which ice or warm water can be put to control the temperature (for many animals, at any rate, both among fishes and invertebrates, we have found by experience that a low temperature is a very important factor in maintaining life when the animals are crowded into a small amount of unrenewed water); to provide both the current and the continuous respiration by installing a propeller device of enameled iron kept in motion by means of a spring motor.

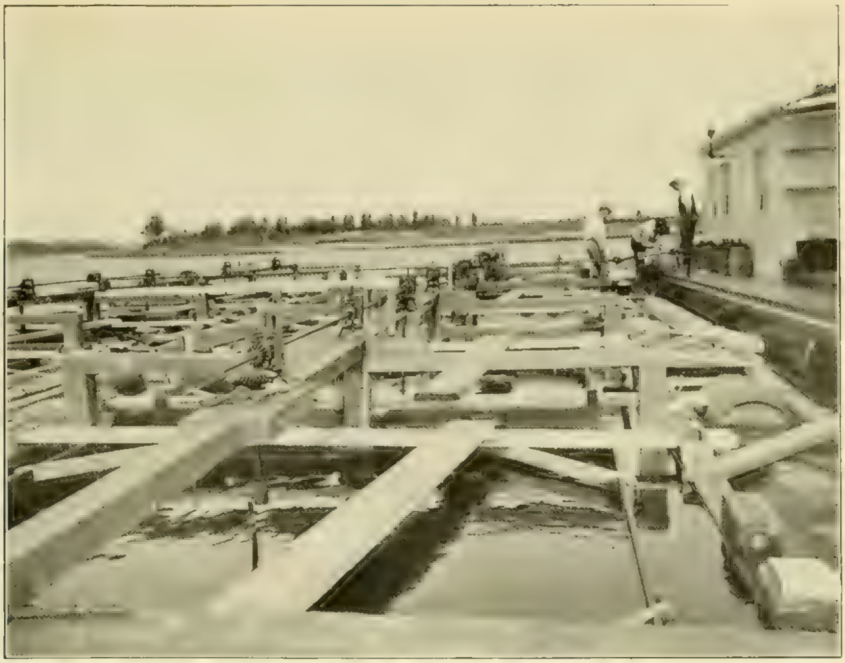

FIG. 3.—Starboard side, looking aft, inside float. Shafting system and general arrangement of cars

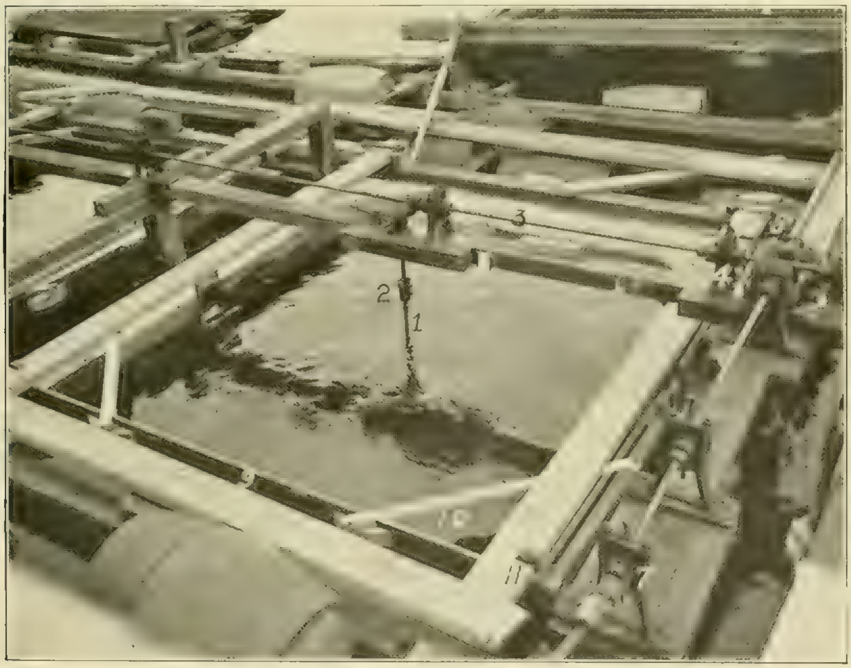

FIG. 4.—Car with propeller in motion. From propeller the shafting may be followed back (1–8) to the universal joint. 1, propeller shaft; 2, sleeve coupling; 3, longitudinal shaft; 4, adjustable shaft hanger; 5, gear trains from longitudinal to transverse shafts; 6, transverse horizontal shaft of float; 7, shaft hanger; 8, ball joint connecting shaft with that of house boat; 9, edge of rearing box; 10, brace across corner of rearing box; 11, holding-down plank mortised into corner post; 12, shaft beam.

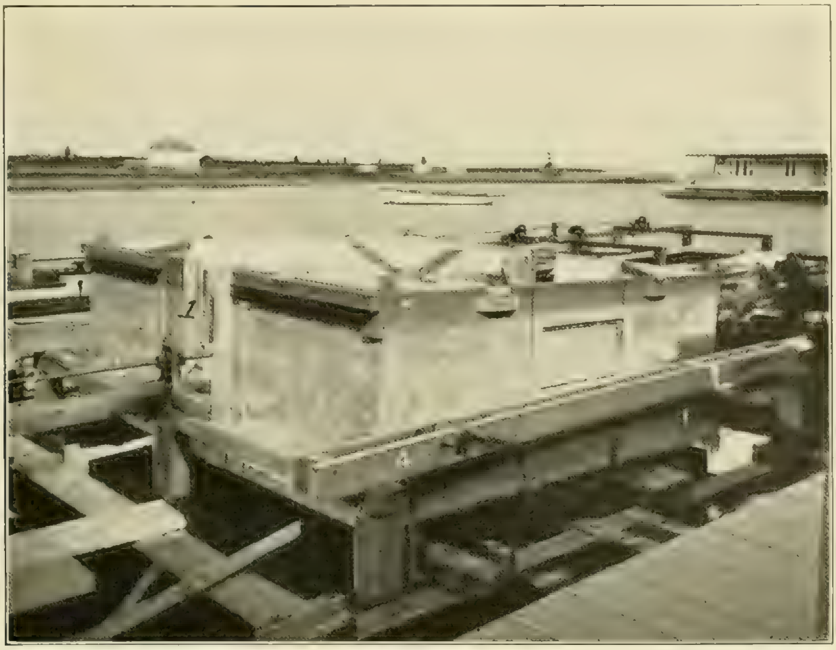

FIG. 5.—Rearing car raised and held up by portable windlass. 1, slot in end of car through which the longitudinal shaft runs when car is raised; 2, longitudinal shaft; 3, side window of car; 4, portable "horse" and windlass.

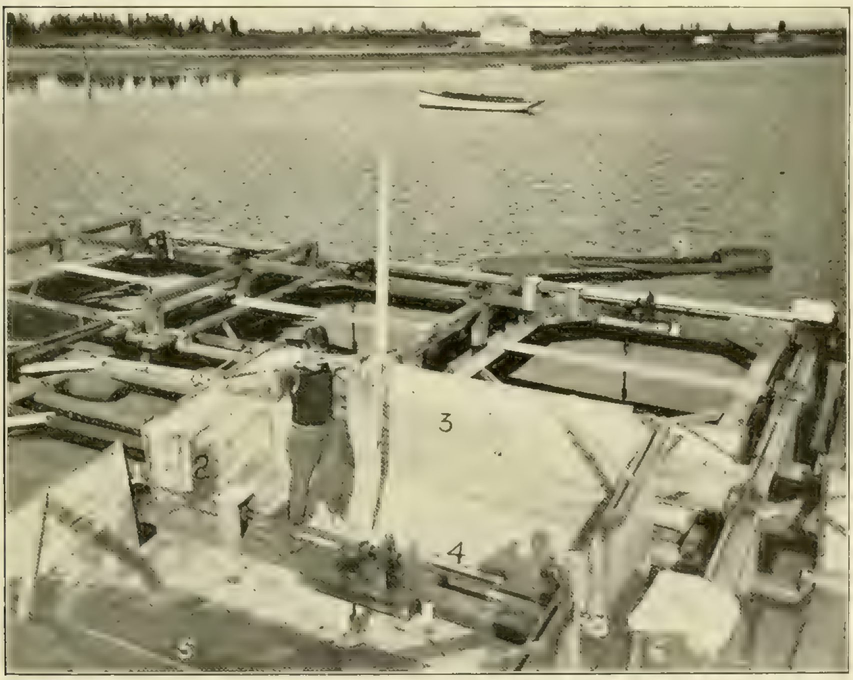

FIG. 6.—Interior of rearing car, and propeller. 1, slot in end of car; 2, doors for closing the slot; 3, side screen windows; 4 and 5, bottom windows; 6, box covering gear trains; 7, transverse shaft; 8, longitudinal shaft; 9, towing car. The arrangement of shafting on farther float can be seen.

FIG. 7.—Lifting the disconnected propeller out of the water. The upper portion of the shaft with the sleeve coupling is seen at 1.

FIG. 8.—The propeller removed, showing disconnected shaft. The upper part of the shaft and the coupling are faintly visible under the shaft beam. The photograph shows well the size and shape of the propeller blades.

FIG. 9.—Cleat at the end of the holding-down plank, showing the detail (1).

FIG. 10.—The cleats being removed, the car rises part way by its own buoyancy. Opening doors of the slot at end of car to admit the longitudinal shaft beam allows the car to be entirely raised. 1, cleat; 2, holding-down plank; 3, longitudinal shaft beam; 4 and 5, side windows.

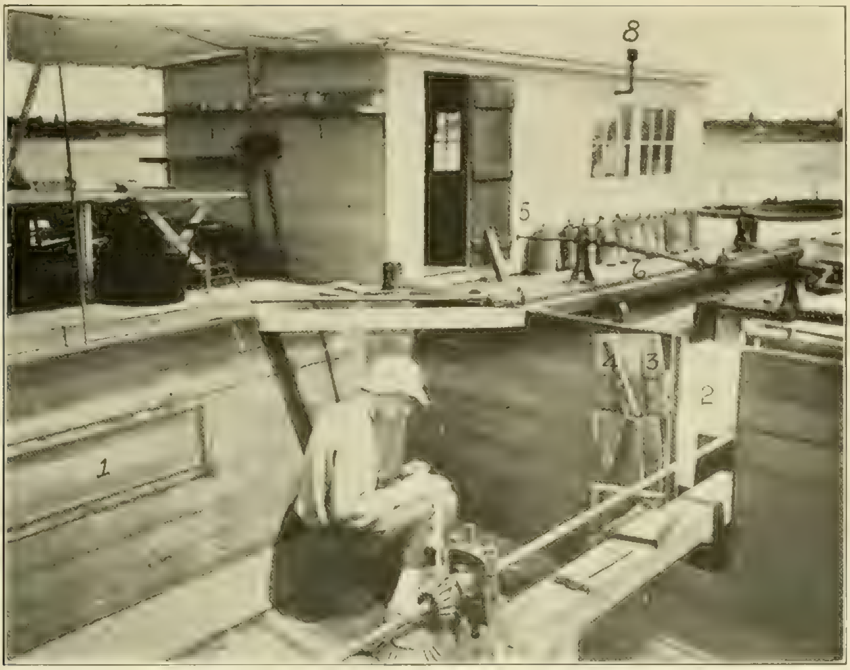

FIG. 11.—Interior of rearing car. Preparing to calk small cracks before lowering the car. 1, side window; 2, end slot; 3, doors for same; 4, buttons to hold doors shut; 5 and 6, the transverse shaft, universal joint, and sliding sleeve; 8, exhaust and muffler.

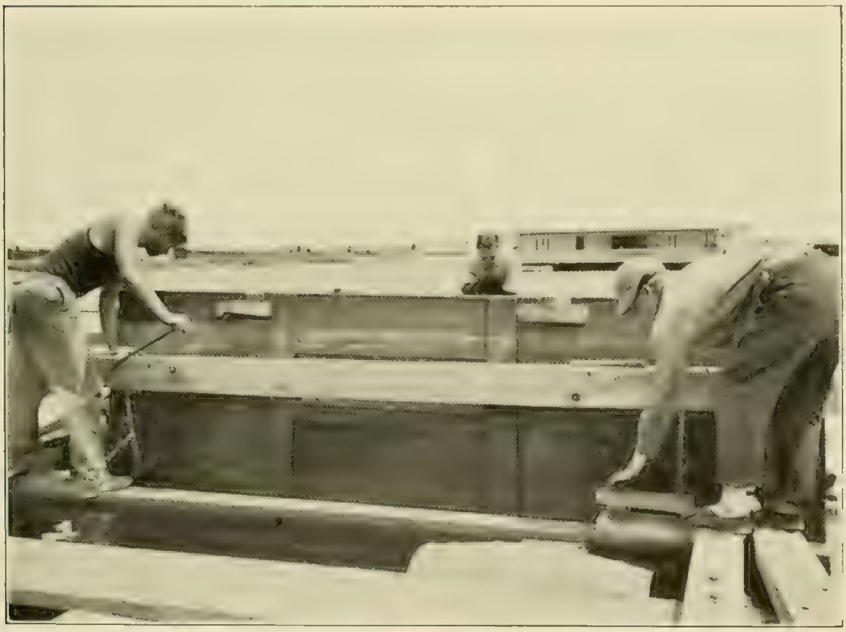

FIG. 12.—Raising the car by means of windlass. Ropes from the drums of the windlass are fastened by hooks to rings in the lower corners of the car.

FIG. 13.—View of interior of a car, showing filter of gravel and sand placed over one of the bottom windows. Arrangement described in text for rearing very minute larvæ, or those for which screen windows are dangerous. The car is calked tight; water is poured over the top by bucket chains (see fig. 15, pl. XCVII) and its only exit is through this bottom filter.

FIG. 14.—"Filter car" in operation. Short propeller hung about 18 inches below the surface. 1, trough with canvas lining for conducting incoming water; 2, floating shallow bag of scrim used in hatching certain fish eggs. The arrangement of shafts and gears shows well in the figure.

FIG. 15.—Filter car, same as figure 14, plate XCVI, showing bucket chain in operation. One of the buckets has just emptied itself and the stream of water is faintly shown running into the trough.

FIG. 16.—Filter car with canvas lining. Chain buckets on left. The propeller blades may be seen in the water.

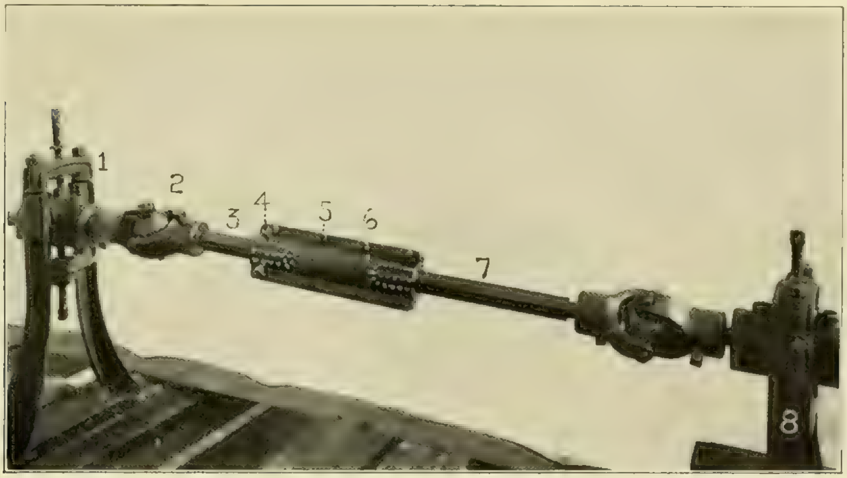

FIG. 17.—Detail of device for extension and universal movement. 1, adjustable shaft hanger on house boat; 2, ball joint; 3, square shafting, fastened by set screws into ball joint at left, and also (4) into sleeve; 4 and 5, screws through flanges of sleeve; 6, oil holes; 7, square shaft which slides in and out of sleeve; 8, shaft hanger upon side float.

FIG. 18.—Detail of lower portion of the propeller shaft and its socket in floor of car. 1, propeller shaft, made of gas pipe; 2, short portion of shaft made of steel, to fit into the socket (6); 3, four-way pipe coupling; 4, gas pipe to which blades are strapped; 5, strap holding propeller blades; 6 and 7, socket and flange; 8, upper disconnected steel portion of the propeller shaft; 9, shaft beam; 10, window in bottom of car; 11, base of propeller blade, showing in section the shape.

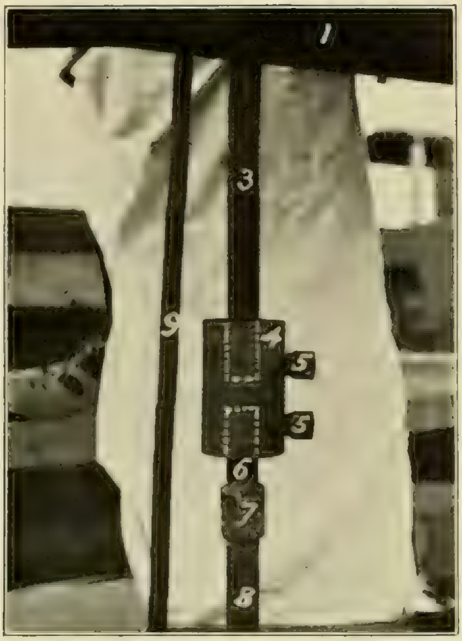

FIG. 19.—Detail of propeller shaft couplings. 1, underside of shaft beam; 3, upper steel portion of shaft, which bears gear on top and enters sleeve coupling below; 4, cast sleeve coupling; 5, set screws holding shafts in coupling; 6, short piece of steel shaft; 7, pipe coupling; 8, lower part of shaft, made of pipe; 9, measuring stick, made of sections 6 inches long.

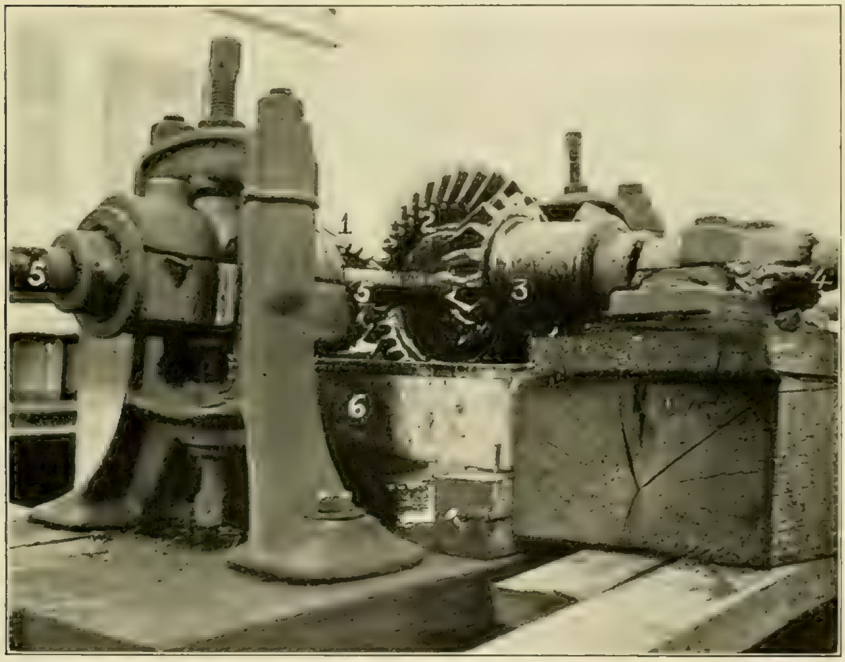

FIG. 20.—Detail of gears on float at junction of transverse and longitudinal shafts. (Compare fig. 4, pl. XCI.) 1, gear on horizontal shaft from house boat; 2, large gear on longitudinal shaft, reducing speed one-half; 3, gear on the inner end of transverse shaft (4); 4, shaft transmitting power to outer float; 5, longitudinal shaft on inner float; 6, oil box.

FIG. 21.—Detail of device for throwing propeller in and out of gear. By pulling the lever the propeller shaft and its gear drop as in fig. 22

FIG. 22.—Device for throwing propeller out of gear. (Compare fig. 21.) This figure shows the propeller shaft gear dropped down so as not to engage the smaller gear on the longitudinal shaft.

A METHOD OF CULTIVATING RAINBOW TROUT AND OTHER SALMONOIDS

By Charles L. Paige

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A METHOD OF CULTIVATING RAINBOW TROUT AND OTHER SALMONOIDS.

By CHARLES L. PAIGE.

CLAIMS OF THE METHOD.

The experiments here described were conducted on Boulder Creek, in the Shasta Mountains, in Shasta County, Cal., in water to which the rainbow trout is native, under most favorable conditions for studying the fish and its habits. The experiments were made independently, with a view to determining a method for propagating trout without stripping the fish and resorting to the process of hatching the eggs artificially.

The claims established by the results of these experiments are:

1. That the rainbow trout (*Salmo irideus*, and probably nearly all the genus *Salmo*) will readily deposit their spawn in runs or races properly arranged; that after spawning the fish may be excluded from the runs or races, to prevent egg eating and cannibalism; that the water can be regulated under control while the eggs are in process of incubation where naturally deposited by the parent fish; that a high percentage of the eggs will produce hardy fry without other care than the proper regulation of the flow of water in the race and the exclusion of such fish or animals as prey upon the eggs, embryos, or young fish.

2. That when the fry appear, as they swim from the nests of the spawning beds of the race, they may be readily diverted into nursery pools connected with the race without any handling whatever, and that they may be there cared for and fed, if necessary, more advantageously than they can be in troughs or crowded colonies.

3. That pools made ready and filled with water for some months before the fry hatch will accumulate natural food for the fry, and where they are connected with an open race of running water this food supply is continued by the natural succession of aquatic and insectiverous food that is denied to fry hatched and held under artificial methods.

4. That the fry, having more water area, more varied and natural conditions in the flow of water—such as swift water, shallows, and depths—are not forced to constant struggles; that in an adequate race with side pools they have natural foraging area and may follow their instinct of independent exploration and solitary habits.

5. That the method proposed is superior in that it follows natural conditions governing the propagation and welfare of the fish, only eliminating and providing against the destructive forces, such as floods, drought, the tendency of trout to prey upon the eggs and young, and protection against such other fish and animals as prey upon the eggs, embryos, and young fish.

6. That the proposed method of causing the trouts (and probably under favoring circumstances, most of the salmon) to deposit their spawn in prepared runs or races, and the subsequent care of the nests and the young fish, may be more economically carried out than the artificial method of collecting eggs, impregnating them, and thereafter caring for them, as it is now practiced in most hatcheries, involving expensive plants and skilled attendants.

REPORT OF EXPERIMENTS.

In support of the foregoing claims for the advantages of the system outlined, it is manifestly impossible to submit a portable model or other more tangible evidence than the sketches and particulars herewith submitted. The facts of experiments made are briefly summarized as follows, with the aid of diagrams 1, 2, and 3:

With a series of four ponds, constructed within a few yards of Boulder Creek, in which the rainbow trout are native, water sufficient to provide a flow through the ponds was diverted thereinto by way of an open trench 300 feet in length. The ponds are about 30 by 60 feet in area and range from 2 to 6 feet in depth. Several falls over weirs aerate the water sufficiently. The embankments are walled with bowlders, laid up without masonry, and in all respects the ponds comply with the natural conditions of the stream as nearly as can be devised. The temperature of the water in the ponds ranges from 40° to a maximum of 83° F., the latter high temperature occurring several days in the month of August, 1908, and lasting but a few hours in the afternoons of the warmest days. The fish suffered no ill effects from this extreme temperature, but were for the time manifestly restless and alarmed.

For two years, covering the spawning seasons of 1906 and 1907, from 40 to 100 adult rainbow trout were held in the ponds. These trout were taken from Boulder Creek with hook and line, readily became domesticated, all remained in good condition, and are at present among the largest of the breeding fish in the ponds.

The first season (October, 1905, to April, 1906), the larger of the fish spawned in beds made around the shores of the ponds, and in due time between 100 and 200 fry reached the surface. The little fish, with the exception of half a dozen, disappeared within a month. Five or six only survived.

The second year (1907), while a larger number of the parent fish spawned still fewer fry appeared, and but four of these reached the yearling stage. This

season the fish were closely observed and it was ascertained that some of the smaller fish, apparently nonspawners, invaded the nests and with their noses dug into the gravel after the eggs. None of the fish was ever seen in the act of devouring fry, but the disappearance of the young could be accounted for in no other way than by the assumption that they were devoured by the adult fish.

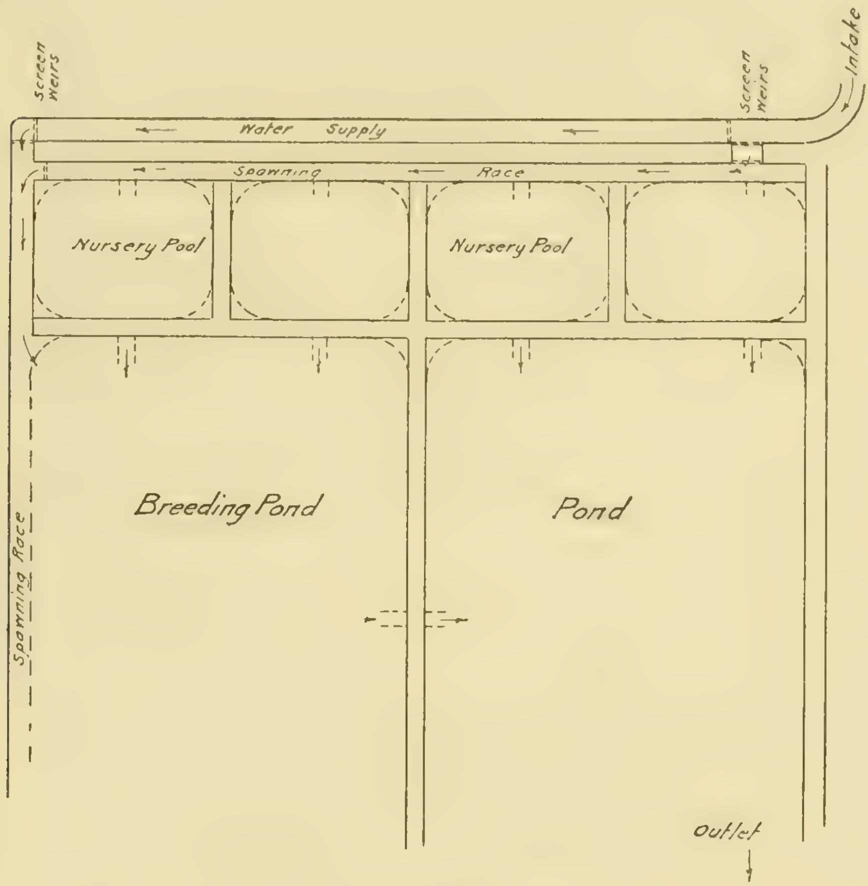
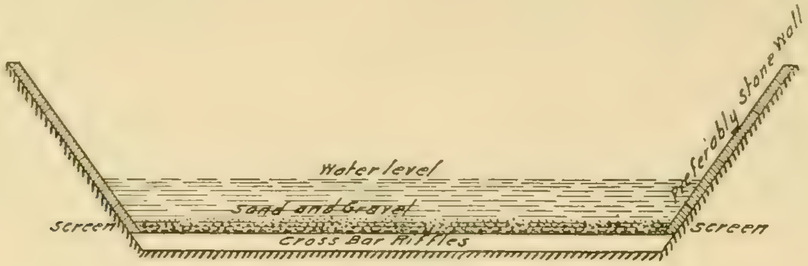


FIG. 1.—Plan of ponds and spawning race.

In September, 1907, a spawning race was constructed and connected with the ponds, substantially as shown in diagram 1, and the inflow water was diverted through the race to the ponds. The race is 2½ feet wide, 100 feet in length, and is paved with stones, loosely placed, and then covered partially with coarse sand and gravel. The race has a grade of approximately 1 in 20, and is made spiral in form, owing to limited ground area. Water affording a depth of 3 to 6 inches passed through it, the gradient giving it a rapid flow.

The fish soon accustomed themselves to the race, and at the spawning time about a dozen pairs of the larger trout conducted their spawning in it. Owing to the aggressive disposition of some of the males, the race proved to be too small for all the fish, and some of them nested in the ponds, as in previous seasons.



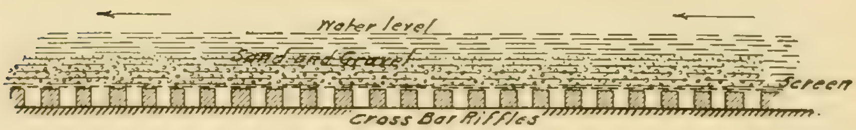
Cross section.

Longitudinal section.

FIG. 2.—Spawning race.

NOTE.—Screen is used to prevent the clogging of the riffles, but with properly proportioned quantities of gravel and coarse sand the screen may be omitted. The eggs and milt of the fish should sink into the riffles with the finer particles of sand, to prevent fish from devouring the eggs during the spawning period.

The race was in the open air, covered at intervals with strips of burlap laid over wire netting to afford shaded portions. The spawners showed no preference as to the shaded or the open spaces, nesting in both. In some instances they

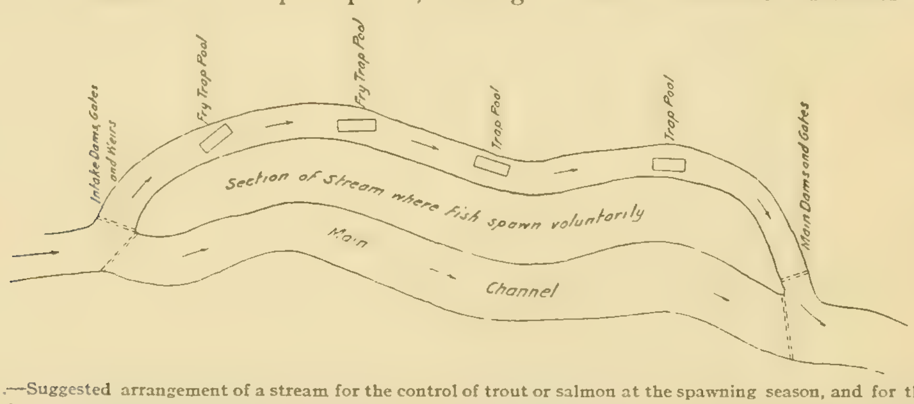


FIG. 3.—Suggested arrangement of a stream for the control of trout or salmon at the spawning season, and for the collection or rearing of the fry after the eggs have been naturally deposited and hatched. Sketch shows side channel, canal or prepared race, with flow of water regulated and controlled by dams, weirs, and gates. Under favoring conditions both channels might be available.

spawned in water too shallow to cover their backs, and in the open sunlight. Wire netting was stretched over the race to protect it from disturbance by birds and domestic animals, but it had no further attention until the fish abandoned

their nests, about April 5. The run was then cleared of all fish, the water partly shut off, and screens placed at each end to exclude fish and destructive animals.

COMPARATIVE RESULTS.

About April 20 fry first appeared in the race, and fine screens were placed to prevent their escape into the ponds or out at the inflow. Two pools had been prepared for them and these were now connected with the race. By June 1 between 2,000 and 3,000 fry had hatched in the race, and these were about equally distributed in the race and the two pools. At the present writing (August 10, 1908) less than a dozen of the fry have died from any cause, and several of these perished by being caught in the screens. The fry now average nearly three months of age and are in thrifty condition, with no evidence of weakness among them.

Not above twelve pairs of the fish spawned in the race, and several of these were small females which were seen upon the nests but a few times, while the larger fish occupied the nests at intervals during six to eight weeks. It is to be considered that trout deposit but few eggs at a time, and this would appear to be a strong argument against the stripping process.

The fry appeared in the race, by careful count and removal, as follows:

April 20	12	April 25	10
April 22	8	April 26	10
April 23	8	April 27	18
April 24	4	April 29	11

Thereafter, until late in June, from 20 to 50 fry appeared daily, and the number then decreased until all had hatched. This may or may not be approximately the ratio in which the eggs were deposited, but it must be of value as proof that they are deposited but few at a time, and covering considerable time.

More than half of the spawners were kept out of the race by the pugnacious males, or elected to spawn in the ponds. Some of these were the larger fish and continued spawning throughout the season. Smaller fish, spawn-eaters, were continuously raiding the nests in the shallows of the ponds. Only about 20 fry appeared during the hatching season, and a dozen of these were saved by being dipped out with a net and placed in the fry pools. None of the others survived.

In conclusion, I desire to submit that these experiments, entailing much labor and time, and observations made under very favorable conditions and carefully recorded, have convinced me that it is not practicable to propagate trout in limited areas of inclosed water, without provision for the protection of both the spawning beds and embryos, and also the segregation of the fry until they are at least six months of age.

I do not believe a simpler, more practicable, or economical method can be devised to meet these requirements than the provision of adequate runs or races, together with nursery pools for the fry, substantially as outlined in this paper.

POSSIBLE EXPANSION OF SHAD-HATCHERY WORK

By S. G. Worth

Superintendent U. S. Fisheries Station, Edenton, N. C.

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

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By S. G. WORTH,

Superintendent U. S. Fisheries Station, Edenton, N. C.

In the past thirty years the methods of shad hatching and distribution have been carried to a high degree of excellence, and it may be said that little is left to be desired in these branches of fish-cultural work. There is an invitation to greater effectiveness, however, in the possibility of carrying the hatchery work beyond its present scope into rearing methods, so that the young fish may be planted after they have reached the fingerling stage and thus enter the open waters with greater chances of survival.

It has been exceptional to employ a gravity supply of water in any shad hatchery, the shad-spawning area being in the coastal plain region where tide water or equivalent conditions precludes the idea of dams, waterfalls, and reservoirs. If lunar tides do not exist then there are wind tides; there are no constant downward flowing streams in the spawning neighborhoods, or if any such exist the country is too low to permit the utilization of the flow. Hence nearly all shad hatching has been conducted in water supplied by steam pumps, with the expense of which it has been regarded as impracticable to undertake pond work of any kind at the shad-hatching stations. The activities have thus been concentrated upon hatching eggs and liberating the embryo fish product, attempt to carry the work beyond this point being exceptional. It was limited, in fact, to the Fish Ponds, Washington, D. C., a station now abandoned.

At that station, however, the rearing of shad was taken up in 1888, and continued until the abandonment of the establishment, in 1906, with highly satisfactory results. In the Commissioner's Report for 1888, page xxviii, appears the following statement:

> Nearly 3,000,000 shad fry were placed in the west pond in May, 1888. These were held in the ponds during the summer, but were not fed; on the natural food found in the ponds they made rapid growth. In October, when the young shad were released in the Potomac River, they had attained the average length of 3 inches. It was not possible to determine by actual count the number of fish liberated, but conservative estimates placed the number at 50 per cent of the number of fry placed in the pond. These results were as satisfactory as they were unexpected, and indicated a new departure in fish-cultural work which promises important consequences.

The experience of 1888 was repeated with scarcely a variation for ten years or more. In other words, the rearing of shad fry was a success throughout. In my intimate association with the Fish Ponds and the Superintendent, the late Rudolph Hessel, and with the Central Station, which supplied the fry, I heard no suggestion of disappointment from any source. On one occasion I understood that some of the fingerling fish, on close examination, were found to be alewives, or river herring, but it may be said that any pond of a tidal or semi-tidal kind in the region of the river herrings is almost sure to contain some of their young. In the experimental ponds at Edenton Station the screens were kept in all the time and adult herring could not enter, but eggs were deposited on the outer surface of the wire mesh and the resultant fry, along with many others, perhaps, swam through the meshes. In fact, any screen that would allow the water to drain or waste from a pond would scarcely exclude the minute young of the river herrings. A noteworthy feature of the shad-rearing in connection with the work at the Fish Ponds, in view of the successful results, was the inferior quality of the fry supplied to the station. I personally know that, for a number of seasons, it was "the weak fry," "the early and weak fry"—fry that were of less than average vitality—that were consigned for these experiments.

Not only was the rearing of shad at the Fish Ponds a striking success, but an experiment at the more distant Neosho Station, in Missouri, under the late Superintendent William F. Page, was equally gratifying. In the commissioner's report for 1893, Superintendent Page says:

> In addition, 200,000 fingerling shad were liberated in waters tributary to the Gulf of Mexico. Their number could not be ascertained except by estimate, owing to the fact that these fish can not be successfully handled. They were the product of 700,000 fry sent from Washington in the preceding June. In preparing for their release the hatchery branch was, in October, cleared of shoals, drifts, and aquatic plants for three-quarters of a mile, to a point where it empties into Hickory Creek. Early in November, when the branch was swollen by rain water, the 6-months-old fish were allowed to pass through open gates. They were some hours in escaping—a continuous silvery mass. These were the first fingerling shad planted in waters tributary to the Gulf of Mexico.

It will be well to note also what follows in Mr. Page's account, as below:

> The pond which contained the shad was infested with crawfish, 1,750 pounds being removed and destroyed between August 3 and October 31. These were estimated to be 70,000 in number. By some unaccountable means black bass of the large-mouthed variety were also present. In preparing for receipt of the shad the pond had been drawn in November, 1891, and the bottom exposed for three weeks, and in the following April the process was repeated, all water connections with black bass ponds having been broken and an independent supply being established. On August 3, the intruding fish being observed, a hook and line were brought into use, and on the first day 5, averaging $1\frac{1}{2}$ pounds each, were caught, and by October 31 the catch had reached a total of 152. It is believed that they burrowed in the mud, surviving the absence of water during the two periods mentioned.

The fish-cultural reputations of both Mr. Hessel and Mr. Page assure acceptance of their figures; and we know, of course, that no river herrings were among the fingerlings released from Neosho station, while the large output notwithstanding the crawfish and intruding black bass is a demonstration of the certainty of results in shad rearing where the right kind of ponds are employed.

The simplicity and the minimized cost in the rearing of shad makes it entirely practicable to entertain the idea that perhaps all of the output of the shad hatcheries might, in a short time, be subjected to the process. Deep ponds are not required, 3-feet depth being ample. Necessary conditions are to have ponds so arranged that the fingerlings require no handling—for their scales drop off at a mere touch—and to exclude as many natural enemies as possible. The first condition can be secured in either tidal or upland ponds, for the latter can be arranged in a series of two or more, each one backing the head of water against the gates of the next higher, the one nearest the stream being tidal or semitidal. The uppermost ponds could be emptied serially into the next lower down until the one next the stream contained all, when its gates could be opened. In tidal ponds there would be difficulty in excluding natural enemies, owing to the impossibility, ordinarily, of drying the bottom and keeping it exposed.

Lands available for the desired purposes are to be found throughout the shad region, and twenty years ago I pointed out the ponds used as meadows by farmers below Gloucester City, N. J., as exactly adapted to such use, they having automatic gates which turned rain water out at low tide and closed against the rising Delaware River lunar tides. Lands suitable for shad-rearing ponds would as a rule, be too low for agriculture, and their market price, or annual rental, would be inconsiderable. It has not been determined how large the ponds should be, but the one so long used for rearing at Washington contained about 5 acres. While such work should be directed intelligently, the chief cost would be the maintenance of a faithful watchman during the few months the shad were held.

In view of the extraordinary interest that attaches to the shad along so great a seaboard—Maine to Florida—by all citizens, of all degrees and conditions, and with the renown that shad culture has brought to its originators and sustainers, the work would seem to merit the bestowal of all rational culture methods that are really apparent. The rearing of the young fish can not be considered other than a strictly rational proposition, while, at the same time, it has passed all experimental stages. Welcome the day when all the shad fry produced at the shad-cultural stations shall be reared to fingerling size before being liberated in the open waters.

THE COMPARATIVE VALUE OF FOODS FOR RAINBOW TROUT AND OTHER SALMONOIDS

By Charles L. Paige

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

THE COMPARATIVE VALUE OF FOODS FOR RAINBOW TROUT AND OTHER SALMONOIDS.

By CHARLES L. PAIGE.

To demonstrate the comparative value of different kinds of food for young salmonoids with any degree of exactness must necessarily entail very patient and careful investigation. The fishes experimented with will have to be maintained in separate pools, under identical provisions of environment, water supply and area, temperatures, and the possible supplies of natural food carried by or existing in the water or in the pools themselves. Where there exists wide diversity of opinion as to food values for the higher orders of animals, to demonstrate the values of such atomic particles as are collected by the young fish will tax the powers of the most exact scientific analyses. Any demonstration of the maintenance of the fishes will in itself be subject to question as to specific hereditary influences, climatic or aquatic conditions, prevailing habits of the fishes, and many other circumstances for consideration.

After experiments and study covering a period of many years, supplemented by close observation of the fish in small areas of inclosed water, I can suggest no new form of food artificially prepared superior in any respect to that commonly used in most hatcheries where young salmonoids are fed. For fry I should prefer these foods in the order here named:

1. Raw beef liver, finely ground, for the first five days or week.
2. Fresh lean meat finely ground.
3. Any available fresh lean meat mixed with increasing portions of wheat middlings, fed either in the raw state or after being cooked as a mush.

In the preparation of any meat food (after five or six days feeding of raw liver alone to newly hatched fry) the fresh liver and meat should be thoroughly ground together with from one-fourth to three-fourths of its weight of wheat middlings. The middlings, in itself good food which will sustain fish indefinitely, is particularly valuable in absorbing and holding the juices of meats and makes a mixture of about the right consistency and gravity to remain in suspense or slowly sink in water, while it is easily distinguished by the fishes once they are

accustomed to it. It is a cheap and generally available staple. Food prepared as described may be readily dried and preserved for emergencies where a fresh supply of meat is lacking.

That millions of trout and salmon fry have been and are being maintained in overcrowded hatching troughs upon a diet of beef liver would appear to be positive evidence of its great value, while it is commonly as easily and cheaply obtainable as any form of animal food.

The chief object of this paper, however, is to suggest that young salmons and salmonoids reared in captivity should be given the minimum quantity of artificial food and a maximum area and flow of water containing their natural food, for which they should be permitted to forage. Prepared food should supplement the natural supply where water area is overcrowded with young fish, or where drouth, cold, or other climatic conditions interfere with the normal natural supply. In support of this view is offered the following summary of well-known or readily ascertained facts and examples:

1. That along the salmon rivers and trout streams fry existing under natural provisions are commonly in excellent physical condition, mortality among them being mainly caused by abnormal disturbances of the nests, such as floods, drouths, or extraordinary climatic changes, or by the depredations of natural enemies, birds, reptiles, and other animals.

2. That salmonoids are not surface-feeding fishes exclusively, but seek food suspended in the water and on the shores and bottom surfaces accessible to them; and that of necessity they must collect more or less vegetable and sedimentary matter; in fact, that they are rather omnivorous than piscivorous or carnivorous fishes.

3. That under normal natural conditions a continuous succession of seasonable aquatic and insectiverous foods, much of which will embrace vegetable matter in some form, is supplied to the young fish.

4. That owing to the minute particles of food matter collected by newly hatched salmonoids, it is doubtless impossible to distinguish with accuracy the natural or instinctive selections made by them, or to determine nutritive values.

5. That it will appear that suitable natural food for salmonoids is abundant in the waters wherever trout and salmon spawn, and that the most available, economical, and scientific provision for young salmonoids may be made in the preparation and adaptation of sufficient water area in normal natural condition, but subject to control as regards floods, drouths, freezing to extremes, and the exclusion of destructive animals. Controlled areas of stream or prepared runs should provide for the absolute regulation of the water flow, and should contain trap pools or other devices for collecting the fish, excluding them at the end of the spawning season, and finally reducing the flow of water to a minimum for the purpose of capturing the fry or young as may be desired.

APPARATUS AND METHODS EMPLOYED AT THE MARINE FISH HATCHERY AT FLÖDEVIG, NORWAY

By G. M. Dannevig

Director Flödevig Hatchery

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By G. M. DANNEVIG,
Director Flödevig Hatchery.

The main point in artificial propagation of marine fishes is to hatch the greatest possible number of fry at the least expense. To attain this end the spawning fish must be treated so that they can yield the greatest number of well-developed eggs; the fertilization must be perfect; the incubators must be able to hatch the greatest number of fry in the smallest space, must be easy of access, and easily cleaned. The following description of the Flödevig hatchery for salt-water fish will show how far the above-stated conditions have been attained.

Main features of equipment.—The Flödevig hatchery is situated on the seacoast near Arendal, Norway. The principal parts are a main building, having on the lower floor 42 hatching apparatus, a water wheel, and an aquarium, and on the upper floor, an office, laboratory, egg collector, etc.; an engine house with boiler and pump capable of delivering about 100,000 liters of sea water per hour; a spawning pond, dimensions 19 by 6 by 3 meters; and a larger pond 34 by 22 by 5 meters, used as a reservoir for sea water. (Fig. 1.) These several parts will be more fully described later on.

Beginning the season's work.—When the spawning season commences, early in February, the pump is set going and the ponds filled with sea water. To insure as far as possible a high and uniform salinity, the water is pumped up from the bottom of the bay, a depth of about 8 fathoms. If the weather has been cold, the concrete walls of the ponds will have a temperature below freezing point; and if so, the pumping must go on for several days until they have the same temperature as the water pumped in.

The spawning pond must be covered to keep out snow, rain, and to some extent, light. Direct sunlight is apt to blind the fish.

The spawners and the spawning pond.—When the pond is in order, the spawners are put in and may now be left to themselves. The proportion between male and female is something like 1 to 4. The fish must be fed regularly, say three or four times a week. Herring are chiefly used, but other fish containing much oily matter, as saithe, whiting, or haddock, are preferable. The pond at Flödevig will hold about 350 cubic meters of water,

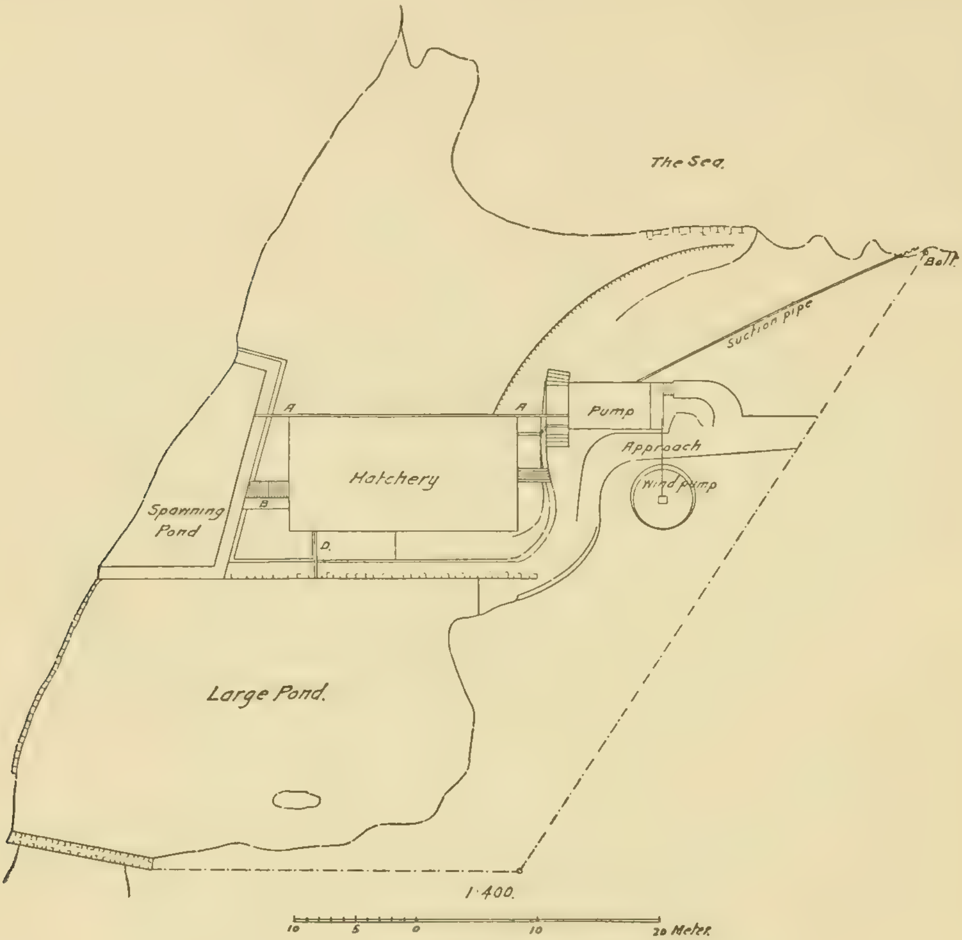

Fig. 1.—Plan of Flödevig hatching station.

sufficient for about 2,000 spawners of medium size. The water supply must be regular and proportionate to the number of fish—at Flödevig 30,000 to 50,000 liters per hour.

In feeding the fish a certain quantity of food and offal will sink to the bottom, and together with unimpregnated eggs, excrement from the fish,

etc., pollute the bottom layer of the water. To prevent the spawners from coming in contact with this the pond is provided with a wooden flooring, about 1 foot over and above the highest part of the bottom, and with a

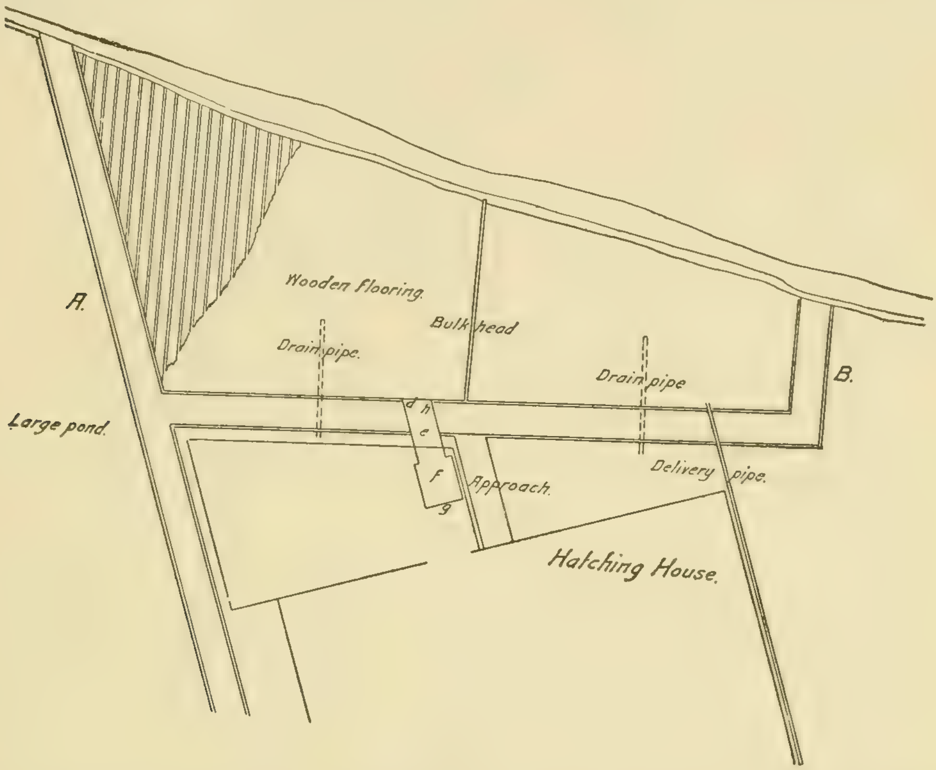

FIG. 2.—Spawning pond. (Plan.)

space between the boards of about 1½ inches. Through these openings the impurities will sink down into a sort of funnel-shaped cellars, provided with

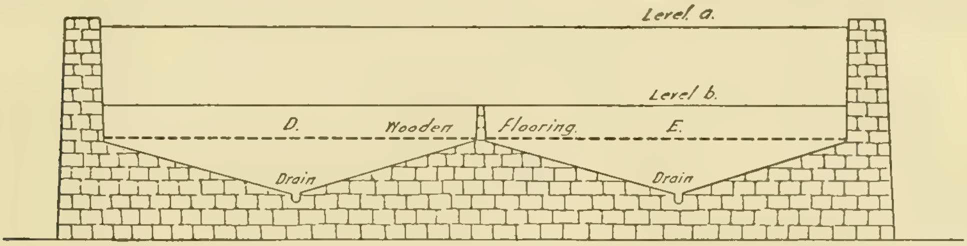

FIG. 3.—Same as figure 2, showing section A–B.

4-inch drainpipes in their lowest part. (Fig. 2 and 3.) These drains are opened about a quarter of an hour every day. In spite of these precautions, however, the bottom water will, after a time, be contaminated to a

degree that becomes dangerous to the fish, and a thorough cleaning out becomes necessary. This is effected in the following manner:

The drains are opened and the water, the surface of which usually is at level *a*, is allowed to run out till it reaches level *b*. (Fig. 3.) The pond is then, by the watertight bulkhead, divided into two compartments, *D* and *E*, and with a number of fish in each compartment. Supposing *D* is to be cleaned first, the water in *E*, under continual renewal, is kept level with the top of the bulkhead, while it is lowered still more in compartment *D*, until about 1 foot above the flooring. The fish are then caught with dip nets and lifted over the bulkhead into *E*. After this is done, all the water is let out from *D*, and the place scrubbed and washed thoroughly. To facilitate the work, the middle part of the flooring ought to be made like a hatch to be lifted off, as cleaning underneath is necessary.

After cleaning, compartment *D* is filled again, the fish lifted in, and *E* cleaned out in the same manner. How often this is to be repeated depends on the number of fish in the pond, the nature of the food, and on the specific gravity and temperature of the water. I have never had occasion to do it more than three times in the season; usually once or twice.

The spawning.—With the exception of the necessary handling when cleaning the pond, the spawners need not be touched during the whole season. If properly fed, and with a constant renewal of the water, they soon will become accustomed to their prison life, and in a short time be so tame that they will take food out of the hand. Consequently the fish will thrive well, and the development of the reproductive organs, as well as the spawning, will proceed in the ordinary manner, just as if the fish were living under natural conditions.

The pond, however, has one great advantage. All the eggs are sure to be impregnated, as the whole volume of water, practically speaking, is filled with sperm, a result of the great number of spawners crowded together in a narrow space.

The cod generally spawn in the evening between 8 and 11 o'clock, and, provided the water has a specific gravity of 1.021 or more, the eggs will float up and form a thin layer on the surface of the pond.

Collection of the eggs.—I have mentioned above that the pond receives from 30,000 to 50,000 liters of water per hour. The outlet is shown at *d* (fig. 2), and is formed as a depression or cut in the front wall, 3 feet wide and 1½ feet deep. Its continuation is a wooden chute *e* of the same dimensions leading into a receiver *f* somewhat broader and deeper than the chute. From this the outflow is through an iron pipe *g*, placed so that its upper end regulates the height of the water in the pond. (See also fig. 4 and 5.)

In the receiver *f* the egg collector (fig. 1, pl. CI) is placed in such a manner that its open end fits exactly to the open end of the chute. The bottom and

back end as well as both sides of the collector are covered with silk gauze no. 40. All water coming from the pond will thus have to flow into the collector, and as this will act as a strainer the eggs will be kept back, while the water continues its course through the gauze netting toward the overflow pipe *g*. As the opening in the wall as well as in the chute is deep and wide, the outflowing current would be too slow to bring all the eggs in the pond into the collector in a

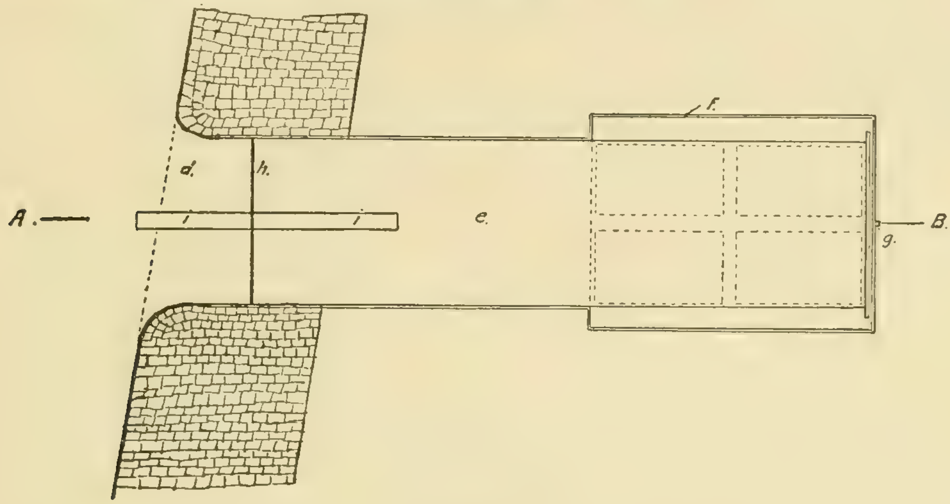

FIG. 4.—Device for installation of egg collector. (Plan.)

reasonable time. To remedy this, a partition or dam has been placed at *h* (fig. 4 and 5), and at the same height as the upper end of the overflow pipe. Instead of a slow current 18 inches deep, we will now have a strong current half an inch deep, and as the eggs float at or near the surface of the water, all of them will in a short time, say two or three hours, be drawn into the collector.

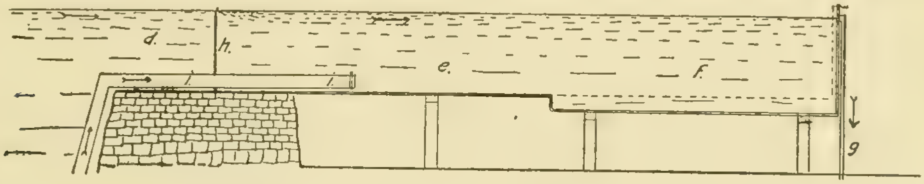

FIG. 5.—Same as figure 4, showing section A–B.

I have mentioned above that the cod spawn in the evening. Consequently all the eggs would be in the collector at about midnight, and have to remain there crowded together till the men arrive in the morning. As this is not desirable, the surface outflow is stopped in the evening and the wooden pipe (fig. 2), which draws the water from a greater depth, is opened, and thus the eggs will remain quietly at the surface of the pond till morning when the surface current is turned on again by closing the wooden pipe.

Cleaning the eggs.—It can not be avoided that a certain quantity of fatty matter, always floating on the surface of the pond, will be drawn into the collector along with the eggs, and form a layer on top of the water. The greater part of it can easily be removed with a stick passed horizontally along the surface, but some will always be left and have to be taken up along with the eggs, in the sort of shovel, covered with silk gauze, which is used for this purpose.

The eggs and whatever is mixed with them are put into an oval bath or a similar vessel, not too deep, and with just enough water to keep them floating. Fresh water is then poured on, which causes the eggs to sink, while the fatty matter remains at the surface. This is poured off, fresh water again added,

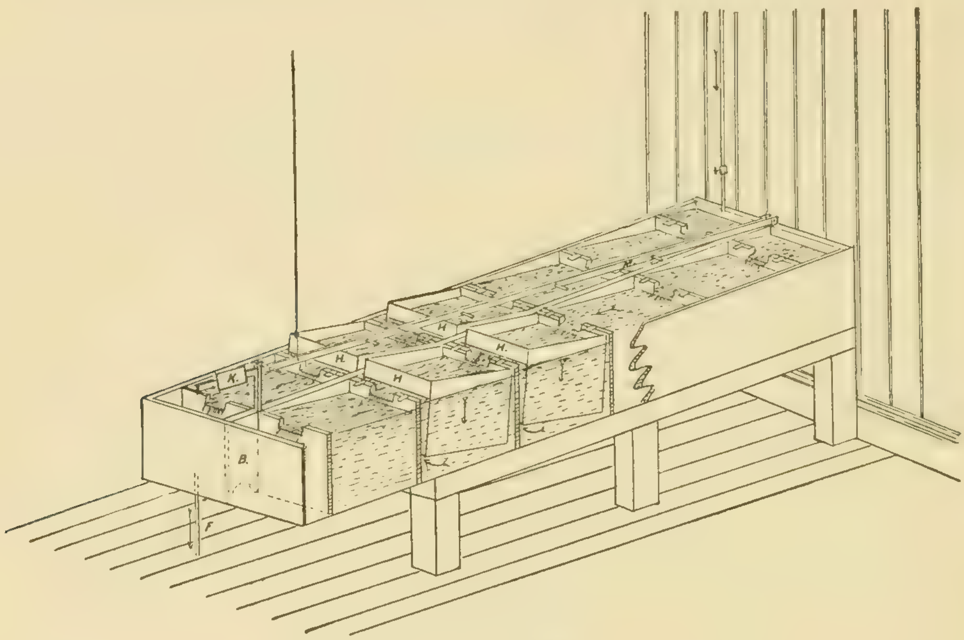

FIG. 6.—Hatching apparatus.

and when this process has been repeated two or three times, the eggs will be clean. After this the vessel is filled with sea water, and, if necessary, a little salt is added. The eggs will now float at the surface and may be taken out and measured as usual. The collector has to be taken out and cleaned one or two times a day.

The hatching apparatus.—If cod eggs were scarce and difficult to obtain, the main point would be to hatch the greatest possible per cent of the eggs. As this is not the case, the question must be to hatch the greatest number of fry for area of hatchery and hatching apparatus, and at the least possible expense. It is from this point of view that the methods used at Flödevig have been invented. The hatching apparatus shown in figure 6 is 7 feet 6 inches

long, 2 feet 3 inches broad, and 11 inches deep inside. By a partition board in the middle it is divided lengthwise in two compartments. These are again divided crosswise in 7 compartments each, the first and last pair being 4 and the others 15 inches long. They are all watertight with the exception that the smaller ones communicate with each other through an aperture in the center-board *B*.

In the top of each of the transverse boards is a depression 1 inch deep and 3 inches wide, into which is fixed a brass spout (fig. 8).

The egg box, or incubator, shown in figure 7, is 12½ inches long, 11½ inches wide, and 10½ inches deep, and made of five-eighths inch white pine. The bottom is covered with silk gauze. It has, similar to the partition board, a depression in the upper edge, also fitted with a brass spout, just large enough to pass outside the former. The incubator is hinged to the transverse board as shown in figure 8.

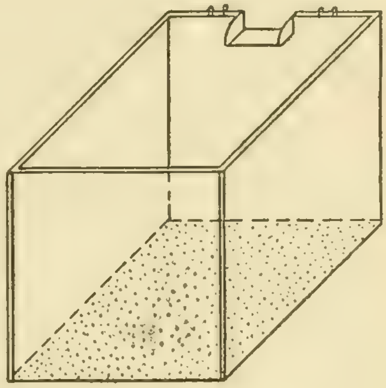

Fig. 7.—Egg box, or incubator.

When the apparatus has been placed in position—slanting 3½ inches—and the water turned on, the small compartments become filled, after which the water passes through the spouts into the next compartments, and so on until the whole of the apparatus is full and the superfluous water escapes through the drain *F*.

As the incubators are made of light wood the loose end will float up and have a position as shown at *H*, figure 6. The circulation of the water after the

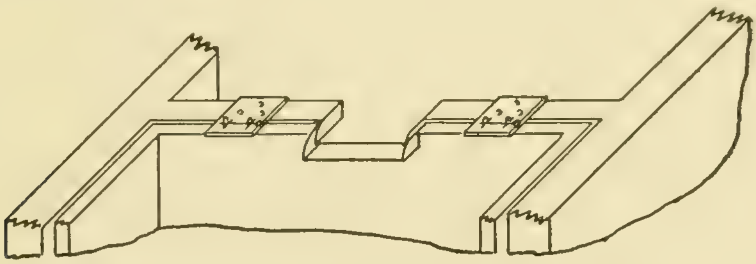

Fig. 8.—Mode of fastening incubator.

apparatus is set going is shown by arrows. As the current is regular, eddies will be formed and the eggs be crowded together in the dead corners, where a great many would die from suffocation. To avoid this an up-and-down movement of the loose end of the incubators has been contrived in the following manner:

An iron rod (*M*), a couple of inches shorter than the apparatus, is joined to this at the upper end and passes down the center between the series of boxes.

It has five transverse pins, resting on the free edges of the boxes, and is weighted sufficiently at K to keep the boxes down in the water. On the contrary, when the rod is raised the boxes will float up. The movement of the rod is brought about by an eccentric (fig. 2, pl. CI), which revolves about twice in a minute and is so arranged that the rise of the rod is slow, while the drop is sudden. This up-and-down movement of the free end of the incubators will make the current irregular, break up the eddies, and keep the eggs in continual motion. The eccentric wheel is driven by a waterwheel that utilizes the outflow water from the egg collector described above.

Hatching.—The usual quantity of cod eggs put into each of the small boxes is 1½ liters, equal to 675,000. The quantity may be raised to 2 liters, but this is rather too much if the specific gravity of the water is low, which very often is the case on this coast. To avoid difficulties in this respect, the water for the hatching boxes is never taken direct from the pumps but from the large pond, which is used as a reservoir and has its overflow pipe placed in its lower part. A temporary fall in the salinity of the water in the sea, even for several days, will by this arrangement hardly be felt. About three days after the eggs have been placed in the incubators, the dead ones will have fallen to the bottom and a cleaning out becomes necessary. This will have to be repeated at intervals as may be required and is easily done, as the incubators can be unshackled in a moment and the eggs are very hardy, so no great care is needed.

When the eggs begin to hatch, the incubators will have to be watched more closely, as the empty shells are apt to fall to the bottom and clog the netting, and a cleaning every day then becomes necessary. At this period great care is needed, as the fry are very tender. The number of days required for hatching the eggs varies according to temperature; at 3° C. to 4° C. the fry will be out in twenty to twenty-five days. The loss in the apparatus during hatching depends very much on the specific gravity of the water, and on the whole the net output of fry will vary between 60 and 65 per cent. The fry are liberated when 5 to 6 days old.

Cost of hatching cod eggs.—As the Flödevig hatchery has been rebuilt and altered several times, it is rather difficult to say how much money has been spent upon it. With the present prices of work and material I should say that a similar station in full working order could be put up for about $5,500. The cost of productions was for the first year about $60 per million of fry, but this price was soon reduced to one-fifth, and at present the fry can be hatched for about $6 per million. In this price everything connected with the work is included.

In 1898 the hatchery produced 412,000,000 of fry from 1,312 liters (590,000,000) of eggs, and under ordinary circumstances and with an expenditure of 12,000 kroner, or $3,150, a similar quantity could be produced every year.

Conclusion.—The above description refers to the Flödevig hatchery in its present state. It would be a long story to mention all the experiments, successful or otherwise, which step by step have led to the present condition of affairs. It is sufficient to say that improvements have been made from year to year and are still going on, so that the Flödevig hatchery, instead of being regarded as an old institution, rather must be looked upon as a growing concern, capable of further development. If the great expectations so justly combined with the question of artificial propagation of marine fishes shall ever be realized to their full extent, the work must be carried on upon an immense scale, and this will first be possible when the expenses have been reduced to a minimum.

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FIG. 1.—Egg collector used at Flödevig, Norway.

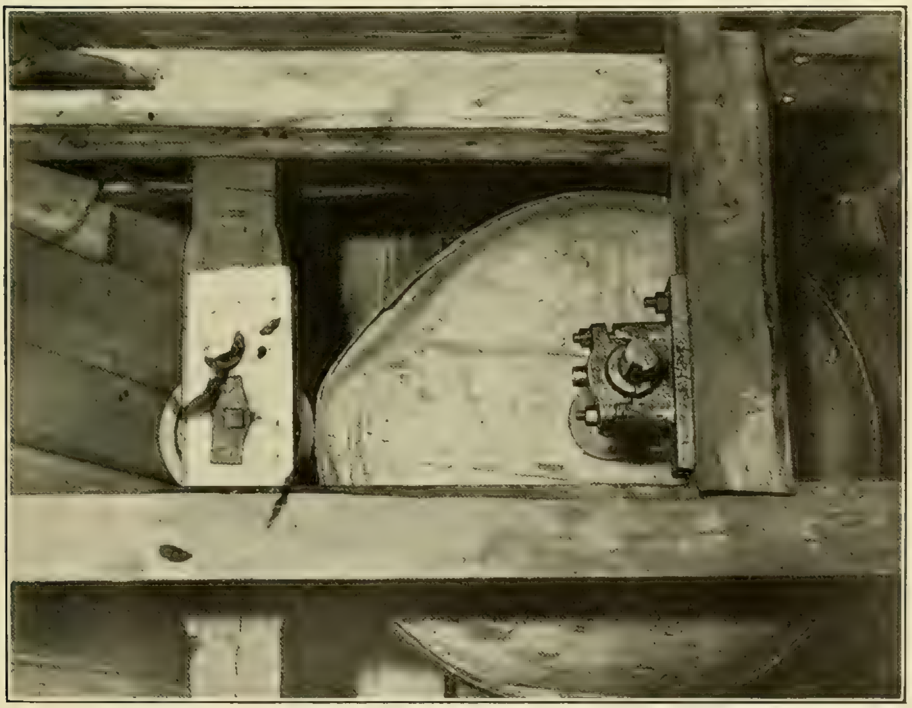

FIG. 2.—Eccentric wheel providing circulation of water in hatching boxes. Flödevig, Norway.

THE UTILITY OF SEA-FISH HATCHING

By G. M. Dannevig

Director of the Marine Fish Hatchery
at Flödevig, Norway

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

THE UTILITY OF SEA-FISH HATCHING.

By G. M. DANNEVIG,
Director of the Marine Fish Hatchery at Flödevig, Norway.

From the middle of the last century the shore fisheries on the south coast of Norway were steadily decreasing, and principally was this the case with cod and flatfish. The cause of the decline was commonly supposed to be overfishing and especially the excessive use of small ground seines, by which the bays and the small patches of clean ground adjacent to the coast were continually swept.

In the beginning of the eighties the state of things became serious. The fishermen as well as the public in general complained loudly, and several modes of protecting the fisheries were proposed. At this period the Arendal Fisheries Society was founded, and being informed that the Fish Commission of the United States had succeeded in hatching cod eggs, it was decided to try this expedient as the only one available that could be used without inconvenience to the fishermen. Consequently a small hatchery for cod was started and maintained for four years, chiefly by private contributions. As an evidence of the great interest in behalf of the enterprise, it can be mentioned that the inhabitants of Arendal, a small place with less than 5,000 souls, during the first five years contributed 24,232 kroner (equal to $6,550) toward the hatchery.

Operations began in 1884 and, as was expected, spawning fish were very scarce and difficult to obtain. The fish market at Arendal was visited almost every day from the beginning of January to the end of March, and the whole quantity of spawn collected was only 28 liters. The next year a small well-boat was provided for buying up spawners on the coast between Bisor and Homburgsund, a distance of about 40 miles, but with no great success, the whole amount of spawn for the following three years being respectively 109, 153, and 144 liters. In 1888 no fish could be had, on account of the ice blockading the coast, and in 1889 no work was done, as the station then was undergoing reconstruction, it having been found desirable to have it removed to another site and enlarged. In 1890 the new hatchery was started with 42 hatching apparatus against 9 in the preceding years, and as there was no chance of getting a full complement of spawners in Arendal or the neighborhood, a well-smack was dispatched

for that purpose. In 1891 there was a marked increase in the cod fishery near Arendal, and still more so in 1892, so that a considerable part of the spawners could be bought there. In 1893 the whole number of spawners was obtained in Arendal, and the spawn collected amounted to 1,000 liters. From that year to the present time there has been no lack of spawners at the Arendal fish market, and the quantity of spawn each year has varied between 550 and 1,326 liters, not according to what could be had, but according to the sum voted by the Storthing for the hatchery. At present it would not be difficult to obtain 2,000 liters if required. It must be borne in mind, however, that natural spawning, introduced in 1890, produces at least double the quantity of spawn compared to the old method, and that consequently the number of spawners can not be calculated direct from the quantity of spawn; but on the other hand it is obvious that the cod has increased greatly in the vicinity since the hatchery was started.

As mentioned above, the hatchery was started in 1884. That year a small quantity of fry, less than 1,000,000, was planted in a small fjord about 10 miles from Arendal. In the following year the neighboring people sent me a letter with the information that a great many small cod had made their appearance, in fact more than the oldest inhabitant could remember.

In 1889 the Bergen Society for the Promotion of the Norwegian Fisheries sent one of their chief members, the president of the propagation committee, as well as the state inspector of fisheries, to the fjord in question to investigate the matter. Their report, dated March, 1889, says that there is no doubt that the number of cod in the fjord has increased and that this is the result of the planting of the fry, and, further, that there can hardly be any doubt that artificial hatching is the right course to take to improve the fisheries.

In 1895 the Storthing decided that to get further proof of the utility of sea-fish hatching fry should be planted in inclosed fjords in the same manner as before and without previous investigations. This was done, and in conformity with the plan adopted our society approached the public where fry had been planted in former years and asked their opinion as to the results. Twenty-two answers came in from parish councils, commercial marine societies, and from private parties and fishermen. The answers were unanimous, and to the effect that an unusual number of small cod made their appearance wherever fry were planted, and, further, that the fish to a great extent were of a color differing from that of the local race.[a]

These documents, however, when laid before the Storthing, caused a member opposed to sea-fish hatching to express a doubt as to their trustworthiness,

[a] The cod on the south coast of Norway vary greatly as far as color is concerned, there being light gray, dark gray, red, and yellow cod, according to race, nature of bottom, food, etc., and, generally speaking, each fjord or stretch of coast has its own peculiar variety.

and the Government ordered its adviser in fishery questions to investigate the matter. His report, dated December, 1896, contains the following particulars: He had visited the principal places where fry had been planted between Fredriksald and Arendal, a distance of about 150 miles, and had questioned fishermen and others, especially such as had not signed the documents. He had in most cases avoided making himself known, pretending to be a private individual who took an interest in the question, and thinks therefore that he got explicit and unreserved answers. Out of thirty persons with whom he had conferred, there were twenty-five who were of a decided opinion that the planting of fry had caused a more or less considerable increase in the number of cod, two who thought there was but a slight increase, and three who had observed no increase at all. In many places the people were certain that they could distinguish the broods planted in the different years and that the size corresponded with the age. The cod now were partly of a color different from what they used to be. He also found the inhabitants very eager to have more fry planted in their fjords, even if they should have to pay for it out of their own pockets.

Since then our society has received a great many testimonials of the same tenor (60 altogether) and as they have been accompanied with cash to the amount of 10,000 kroner for fry delivered, their trustworthiness can hardly be doubted.

In 1903, the Storthing, still doubtful, voted the necessary sums for the investigation of fjords where fry were to be planted. The plan was to have them thoroughly overhauled before and after fry were put in, with the object of ascertaining the approximate number of cod of the year's growth. A seine with very small meshes, 22 fathoms long and 2½ fathoms deep, was used, and great care was taken to have the hauls made in exactly the same places and at the same season, the latter part of September, when the fish would have a length of from 2 to 4 inches, being agreed upon. The work was conducted by me, and controlled by an assistant to the fishery board, an implacable opponent to sea-fish hatching.

Two fjords, no. 1 and no. 2, were thus overhauled in September, 1903. In no. 1 fry were planted the following spring and both fjords again overhauled in September. In 1905 fry were planted in both fjords in April, after which they were overhauled in September the same year. Fjord no. 3 was investigated by me alone, and in the following manner: First, overhauling in September, 1904, with subsequent planting of fry in April, 1905; investigated in September same year. More fry planted in April, 1906, and a final overhauling the following September. As will be seen, all the fjords mentioned have been overhauled three times each. In the first and third, fry were planted twice, in the second only once. The results were as follows:

Fjord No. 1.—About 10 miles long, 1 mile broad, shaped like a horseshoe. Bottom of sand, clay, and mud, the shores mostly rock, covered with algæ,

while the small creeks where the hauls were made were covered with seaweed. One hundred and six hauls were made each time and with the following result: September, 1903, before planting, 426 yearlings; September, 1904, after planting, 1,523 yearlings; September, 1905, after planting, 1,133 yearlings.

Fjord No. 2.—About 1½ miles long by one-third of a mile broad. Bottom as in no. 1. Many of the small creeks liberally covered with sawdust. Twenty-one hauls each time, resulting as follows: September, 1903, before planting, 36 yearlings; September 1904, before planting, 133 yearlings; September, 1905, after planting, 143 yearlings.

Fjord No. 3.—Circular. Two and one-half miles long by 1 mile broad. Bottom as no. 1. Number of hauls 33, with following results: September, 1904, before planting, 454 yearlings; September, 1905, after planting, 756 yearlings; September, 1906, after planting, 953 yearlings.

The main results for the three fjords will be:

Fjord.	Before planting.	After planting.
	Fry.	*Fry.*
No. 1	426	[a] 1,328
No. 2	[a] 84	[a] 143
No. 3	454	[a] 855
Total	964	2,326

[a] Average.

The increase amounts to 141 per cent.

Figures taken from the fishery statistics for the Kristianiafjord, inside of Dribak, begun in 1872, show an average catch of 75,761 cod in the period between 1872 and 1881, and of 58,476 between 1882 and 1891. In 1892, when fry first were planted, the catch was 44,013. Since then there has been a steady increase, and last year the number caught was 114,013. The number of fry planted in the Kristianiafjord since 1892 is about 170,000,000, worth about 5,000 kroner, while the increase in the catch over and above what it was in 1892 is worth about 600,000 kroner.

On the west coast of Norway, where hatching has not been conducted, the cod is gradually disappearing from the fjords.

PROPAGATION AND PROTECTION OF THE RHINE SALMON

By P. P. C. Hoek, Ph. D.
Scientific Fishery Adviser to the Dutch Government

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ENVIRONMENTAL CONDITIONS AND NATURAL HISTORY.

Wherever it is found the salmon is highly esteemed—to the most precious kinds of salmon that of the Rhine unquestionably belongs.

"Old Father Rhine," with his very important tributaries, flows through a very densely populated part of west Europe—at the same time one of the most industrious and cultivated regions of the whole world. The river itself, as you all know, comes from Switzerland, forms the frontier between that country and the Grand Duchy of Baden, passes through a great part of western Germany, then enters Holland, and in that country, with numerous outflows, finds its way to the North Sea. Of the numerous affluents, which together drain a surface of several thousands of square miles, some belong to Switzerland, many belong to Germany, a few to the Low Countries (the Netherlands) nearer the mouth of the river.

It is impossible to treat of the propagation of the salmon of the Rhine without emphasizing the important rôle the affluents play in the economy of this fish. As a rule the Rhine salmon does not propagate on the main river itself, but for that purpose enters one of the tributaries, there to spawn in the upper courses or in the mountainous rivulets and brooks which are in open communication with these upper waters. The main river itself plays only a secondary part, so to say, in the natural history of our fish; it forms the communication, the open highway, between the sea and the very extensive region where the natural propagation takes place. It is now a well-established fact that the greater part of the young salmon hatched in the higher parts of the affluents of the Rhine remain there about a year, living in that time the life of trout, and as 1-year-old fish, in springtime, migrate to the sea. They reach the mouth of the river on their way to the ocean in the month of May, their length being then from 12 to 17 centimeters. Most of these young salmon at that time have already, or at least partly, changed their trout livery (the "parr" costume), with

the well-known transverse black bands, the small red spots, etc., for a more convenient traveling suit of silvery gray, and in this condition they are called "smolts."

The main river, which has served for the passage of the yearlings on their way to the ocean, a few years later conducts the grown-up fish to their spawning places; so the river itself is mainly the binding link between the sea, where the salmon grow up from 15-centimeter large trout-like fish to marketable salmon, and the upper region, where the propagation takes place and the young salmon find a living until they are about 1 year old. The food the young salmon take in the main river during their journey to the sea consists of different insects, and in the lower parts of the river and the estuaries small crustaceans. During the ascent of the larger fish coming from the sea and bound for the spawning places in the river, as a rule no food whatever is taken. The salmon caught during their ascent owe their value as food for man to the rich feeding grounds in the open sea. So it is perfectly right to consider them as a gift from the sea to the lands bordering on the river, the inhabitants of which catch them on their passage. But taking into consideration the fact that the salmon swim up the river at the expense of the fat stored in their muscles, etc., from a general economic point of view it is also evident that the fish are in finest condition on entering the river, and that therefore the lower parts of the river are most to be recommended for the catching of the salmon.

Now, keeping constantly in our mind the importance of the upper regions of the river and its tributaries for the first year of the salmons' life and that of the open sea for their growth until they shall have reached marketable size, I shall first of all point out to you that this normal course of development is not followed by those young salmon which at the end of their first year remain for a second year, and some of them longer still, at or in the neighborhood of their birthplaces. These are nearly all male fishes, and it is a well-established fact that they will be sexually mature (ripe) in the second autumn of their existence, and then even will play an active part in the propagation of the species. Their size is (October–November) from 15 to 19 centimeters, very few being smaller or larger than that size. It has been suggested by Professor Fritsch for the salmon of the river Elbe that all the young males may remain a second year in the upper parts of the river and its affluents. I have been able myself to show, however, that this by no means holds good for the Rhine. I had the opportunity of examining 365 young salmon caught in May during their descent to the sea in one of the mouths of the Rhine, and measuring from 12 to 17 centimeters, and I found that 136 (37 per cent) of these were males and 229 (63 per cent) females. Males and females were exactly of the same sizes, and it can hardly be doubted that they were all of them 1-year-old fishes. That there was a majority of females may, of course, be considered in connection with the circumstance

that the salmon that remain in the river for a second year or longer are to a very large extent males.

Regarding these latter males, another suggestion has been made by myself, viz, that they will never descend to the sea, but will die after once, others twice, perhaps, having taken part in the propagation of the species. This suggestion is based on the fact that no descent of larger young salmon hitherto has been observed, though the means of making such observations have not been wanting. I have not been able, however, to prove in a direct way the exactness of my hypothesis.

Another point to which I may be permitted to call your attention is that when I said that "grown-up" fish return from the sea and enter the river, if possible to reach the spawning places, the age and in consequence the size of these fishes, and their state of maturity as well, are extremely different. It is of course easy enough to determine the size of the salmon entering the river. Miescher-Ruesch, who did the same (in 1878 and 1879) for salmon caught near Basel and who for the first time applied the graphical method afterwards introduced into science for other fishes as the "Petersen method," found that the curve of the sizes of the salmon of the Basel market is one with three tops or maxima, making it clear at once that three different ages were represented, and showing with great evidence at the same time that the difference in age between the youngest and middle-aged salmon was about the same as that between the latter and the oldest fish caught.

To check the results arrived at by the Basel professor, I ordered to be measured for me (1893) a large number of salmon caught near the mouth of the Rhine and offered for sale at the Kralingsche Veer market. From March to December 4,653 salmon were measured, and the curve constructed with these figures corresponds in the main with that given by Miescher-Ruesch for the Basel salmon. The salmon of the Rhine (fig. 1) present themselves in three sizes: Smallest, 54 to 74 centimeters, mean 64 centimeters (2 to 4 kilograms); middle size, 74 to 98 centimeters, mean 88 centimeters (6 to 10 kilograms); largest, 98 to 134 centimeters, mean 106 centimeters (12 to 25 kilograms).

The fishes of different sizes do not enter the river together or in a haphazard way. The different sizes present themselves in different seasons, but they do in one year exactly as in any other (fig. 2).

The smallest fish (grilse) are called St. Jacob salmon in Holland. They ascend the Rhine in July and August, exceptionally few coming in June; they continue to ascend in September, though in smaller numbers than in the foregoing months, and even in October and November a few may still be taken. They are most of them males and they are all of them in so far advanced a state of maturity that they will be able to take an active part in the propagation of the species a few months or weeks or days after their arrival. This holds good

also for the female grilse, though the males are by far in the majority. Of the grilse, as far as our observations go, not more than 17 per cent are females.

The middle-sized salmon (of 74–98 centimeters) are the so-called "small summer salmon" of the Dutch market. They present themselves for the first time in the river in May, and they continue to ascend until the end of the year. They are most numerous in June and July, but they form also a very important

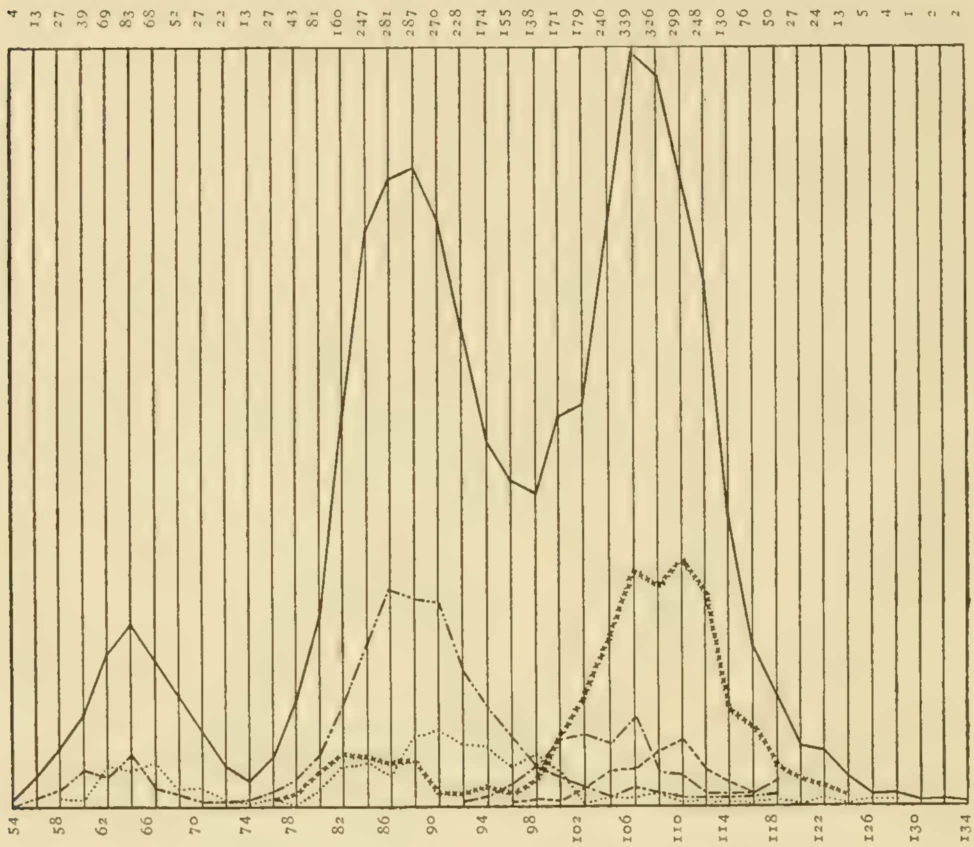

FIG. 1.—Diagram illustrating the sizes of salmon ascending the Rhine. The lengths, in centimeters, are given at the lower ends of the vertical lines. The number of specimens of each length is given at the upper end of the proper line. The total number of specimens measured was 4,653.

————	Salmon of March–December.	—..—..—	Salmon of July.
- - - - - - -	Salmon of March.	....	Salmon of September.
xxxxxxxxxxxxx	Salmon of May.	—.—.—.—	Salmon of November.

part of the August and September salmon. Both males and females appear among these salmon, but the females are in the majority. Though the first arrivals are far from being mature, all these small summer salmon are destined to take part in the propagation of the species toward the end of the autumn.

The large salmon (the fish of 98–134 centimeters) begin to ascend in November, though in some years a few may be taken in October. They are at that time

so far from being mature that until lately they have been considered as quite sterile animals. It has been shown, however, by the investigations of Miescher-Ruesch and myself, that these salmon are by no means sterile, but only immature fish and that they will develop their sexual organs in the course of the year and during their residence in the fresh water. Some are males and some females, the latter, however, being in the majority. They are not very numerous in the winter months, but gradually their number increases; they are very fat and of the highest value as human food. They continue to ascend in spring, are most numerous from March to May, and go on ascending until the spawning time. From the beginning of their ascent until far up in spring they are called "winter salmon;" they are the same salmon, however, as those which from April or May until the spawning time in November and December are called "large summer salmon." Their sexual organs, which are in quite an undeveloped condition in November and December, are slightly more developed in the fish of February, March, and so on. In May their state of maturity is exactly the same as that of the so-called "small summer salmon," which then begin to ascend; for both categories of fishes—and the same holds good for the third category, the St. Jacob salmon, which ascend from July—the date of their entering the river is, generally speaking, a measure of the state of development of their sexual glands. The further development of these organs will take place during their stay in the river itself, and as these fish take no food during their sojourn in the fresh water, it is at the expense of the nutritive matter stored in their muscles, in the lateral muscles of the trunk especially, that the maturation takes place. From this it is clear at the same time that, the "winter salmon" of October and December being by far the most valuable fish of all, through the year the condition of the salmon deteriorates slowly but gradually until they reach maturity, with perfectly developed sexual glands (the weight of which may be over 25 per cent of that of the whole fish), but otherwise in extremely poor condition.

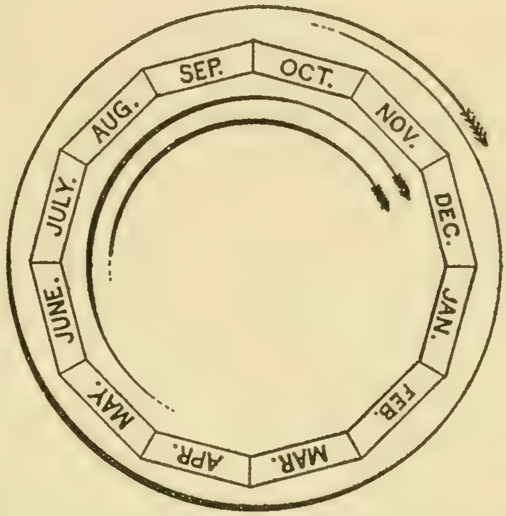

FIG. 2.—Diagram showing the ascent of the Rhine salmon in different months. The outer line, circumscribing the remainder of the figure, represents the salmon of the greatest size, which are called from October to April winter salmon and from May to December large summer salmon. The middle line represents the middle-sized salmon, which are called small summer salmon. The inner line represents the smallest salmon, which are called St. Jacob salmon (grilse). The dotted part of each line indicates when the salmon begin to ascend, the swollen part when their numbers are greatest, the feathered end part when they are ripe for spawning.

I do not wish to enter into detail upon the physiological part of this subject, however; it has been studied with great care by Professor Miescher-Ruesch, of Basel, who on the same occasion published an excellent description of the histological changes of the milt of the salmon, which changes occur during that development of the sexual organs. Later investigations (of Noël Paton and others) have in the main confirmed the results arrived at by the Swiss physiologist.

These are the headlines of the natural history of the Rhine salmon; the same fish as occuring in other European rivers has perhaps not been studied quite so carefully as the Rhine salmon, but from what we know about the other rivers, which after all is not so little, we may safely conclude that the salmon behave about the same all over Europe.

PROPAGATION.

About the propagation of the Rhine salmon few words need be added. We saw that the natural propagation takes place in the upper parts of the tributaries, the spawning places being well known to the inhabitants and being easily distinguished from the shore, especially when the water is clear and the depth unimportant. Some of the fish, however, spawn in the main river itself, spawning beds (Laichgruben) having been observed in the Rhine between Strasburg and Basel, as also between Basel and Schaffhausen. Whether spawning in the main river takes place regularly or only accidentally has never been investigated thoroughly; in fact, even for a fish so much studied as the Rhine salmon, in some regards information is wanting which after all might perhaps not be so difficult to obtain.

The real spawning places of the Rhine salmon, it is easily understood from the foregoing, spread over a wide area situated for the greater part in Germany and for a smaller one in Switzerland. The relative richness in salmon which the Rhine even at present possesses is unquestionably to a very large extent due to the wide reaches of its tributaries, the spawning places of our fish. That richness would undoubtedly be much greater if more salmon were permitted to reach these spawning places, if these places were better protected, that the salmon might propagate undisturbed, and if all the young salmon hatched in the upper regions of the river could safely arrive in the ocean.

There can be no question that on the Rhine relatively few salmon nowadays come to spawning in the natural way. Of some of the tributaries (of the Moselle especially, but of some of the affluents in the Grand Duchy of Baden also) I studied the upper regions in this regard, and the result has not been very edifying. The fish reaching the upper region, the number of which is limited by the fishing in the lower and middle regions of the river, are sought with great eagerness. Though their value as food, especially in the very last days and weeks before the spawning, is, comparatively speaking, a small one, they

represent for the fishermen of the upper regions, most of whom belong to the poorer classes of society, a precious contribution to their earnings. The higher the fish ascend, the narrower the tributaries and brooks, the easier to catch the big fish, which in their particular condition are, moreover, slow and lazy in their movements. In consequence very few fish escape; in other words, the number of those spawning in the natural way is as a rule extremely small. I I do not hesitate to say that if the keeping up of the stock of salmon depended on natural propagation only the salmon production of the Rhine by this time would be very poor.

Artificial propagation has tried, and I think not without success, to remedy this deficiency. A good many of the salmon caught in ripe condition, or nearly so, in the upper regions of the river are used for artificial hatching and from these several millions of fry have been produced annually for many years. They have been set free in the most suitable waters, that is to say, mostly in those smaller brooks and tributaries where the salmon would have spawned in the natural way if man had not interfered with their intentions. An arrangement was made, first by Baden, Switzerland, and the so-called Reichsland (Elsass-Lotharingen) and a few years later (1890) by Holland, the different German states bordering on the Rhine, and Switzerland, annually to set free a certain number of salmon fry, and quantities varying from 4 and 6 to 7 millions of young salmon accordingly were bred each year. They are planted almost immediately after the resorption of the yolk vesicle, sometimes also a little before the young salmon have developed so far. They are distributed over a large area of the upper course of the river, and, as I pointed out before, if possible at such places only as salmon are accustomed to seek to spawn in the natural way. Against this procedure an objection was raised that the distance between these spawning places and the open sea is a long one, and that numerous dangers threaten the young fish during their stay in the upper parts of the river and during their descent to the sea as well. It looks at first sight as if these dangers might be avoided by cultivating the fry near the mouth of the river and by keeping them longer in tanks or ponds at the hatchery; but as only very few ripe fish are taken in the lower parts of the river, the culturist is obliged to collect unripe salmon several weeks before the spawning and to keep them in reservoirs floating in the river until they are ripe; or, if he does not like that way of doing, to order eggs from the upper parts, which eggs, once the eyes of the embryo have become visible, endure the transportation well.

Comparing this way of proceeding with the culture at or near the spawning places, and keeping in mind that it is a well established fact that in free nature the young salmon in the upper regions of the river live at least one year the life of young trout, since studying the salmon and the salmon development I have always been convinced, and am still at the present time, that the most

efficacious way of propagating the salmon artificially is to stick as closely as possible to the natural way and to plant the fry in those mountainous courses of the river where their natural home is found. This is not to shut our eyes to the dangers threatening the young salmon during their passage to the sea—in my opinion the best way to avoid this danger is not, however, to grow them in a more or less artificial way near the mouth of the river, but to stock the natural spawning places so richly that a sufficient portion remains, even if a large number of them is destroyed during their stay in the upper parts and their descent to the sea. The solid ground of nature is in this, as in so many other cases, the best to build upon.

FISHING REGULATIONS.

Now coming to the second part of my little discourse, I prefer to give you the headlines only of the existing regulations of the Rhine salmon fishing. You know that the Rhine flows through different countries, and you understand that regulation of the fishery in such an international river based on international agreement for a long time has been considered as the best—as the only efficacious one. The first serious effort to conclude an international treaty between the countries interested in the salmon fishing of the Rhine dates from 1869, but the war of 1870 postponed for several years the conclusion of such a treaty. New negotiations were taken up about 1884, the treaty was concluded in Berlin in 1885, and has now been in force since August, 1886. Originally it was concluded for ten years, after that period each of the powers interested having the right to break off the engagement with one year's warning. Though the treaty has perhaps not quite satisfied those who expected from it great betterment of the salmon fisheries of the Rhine, there has never been seriously a question of giving it up.

As far as the Netherlands are concerned, as a good regulation of the salmon fishery existed already, important changes were caused by the treaty in two regards only—the closing of the fishery on Sunday and the closing of the fishing with big seines a fortnight earlier (on the 15th of August) than hitherto. These changes are quite in accordance with the general idea of the treaty. Those who fish in the lower parts of the river are to spare a considerable part of the ascending salmon, that those fishing higher up may profit by this and also that part of these fish may reach the upper region, there to spawn. The fishermen of the middle and higher regions, on their part, must also take into consideration the interests of the whole river. They are to spare a part of the ascending fish for natural propagation. They are to take into their custody the natural spawning places and moreover to take care that ripe or nearly ripe fish caught in spawning time are used for artificial reproduction.

Methinks the treaty, which is based on sound principles, has, taken as a whole, worked well. If nevertheless on several occasions complaints have been heard on its efficacy, we must not forget that those who find fault with it most were from the beginning too optimistic in their expectations. After all, human nature is not changed by an international treaty, and the nature of fishermen is as human as that of other people. Those who are interested in the fisheries of the middle and upper river claimed, when the treaty was being closed, a greater part of the ascending fish, and through the treaty's influence they have no doubt received that. What is more natural than that they might go further still in the same direction and should like to receive a greater share still in the future? Those who fish in the lower parts of the river, and by the treaty are compelled to spare more of the ascending fish than they were accustomed to do before, complain that the richness of the river in salmon has not augmented since the treaty was closed. They say, "We did not close the treaty only for giving a good deal of the fish we can catch ourselves to our neighbors of the middle and upper regions, but we did so that the spawning region might be better stocked with breeders. If all the fish, or too many of them, we spare are caught higher up the river, what good can come of our savings?" No wonder that they ask for measures better to protect the spawning fish.

I think, however, that it would be hardly interesting and by no means amusing for you to hear me discuss this question any longer or to go over the different articles of the treaty with you. To understand their meaning, a good deal of technical information regarding the natural condition of the river and its different parts would be necessary, and I should spare you such details. I think it will be more interesting for you to hear something about the actual condition of the salmon fishing of the Rhine.

IMPORTANCE OF THE FISHERY.

I need hardly point out to you, who know about the fisheries of your own country, that it is very hard work for a big and precious fish like the salmon to maintain itself in a river like the Rhine, flowing through one of the most populated and flourishing parts of Europe, where all the circumstances seem to cooperate to destroy it and to prohibit its propagation. It is not only the direct influence of man, whose highly developed fishing industry is disastrous after all, that our fish has to reckon with. Indirectly, regardless of the fisheries, man, by normalization and regulation of the river and its affluents, did what he could to spoil and at several places to close the river for the ascent of the future spawning fish. Man moreover polluted the river with the sewage of his towns and with the poisonous waters of his manufactories, his mines, etc. And man, finally, by developing the river navigation, by using the water for

industrial purposes, all in all did his utmost to modify the stream in a direction contrary to the interests of the ascending salmon and their propagation.

Up to the present, nevertheless, the Rhine distinguishes itself from the other rivers of North Europe (and from those of the Atlantic coast of North America as well) by the relative productivity of its salmon fishery—though I must point out at once that also for the Rhine the figures of the catches have greatly diminished from what they were, say twenty-five years ago. There exist no good statistics of the product of the salmon fisheries of the whole river; favored by special circumstances, however, those interested in the fisheries of the lower parts of the Rhine in Holland, embracing all the larger seine fisheries, have for many years been able to register carefully the figures of all the salmon caught in these waters. These are the fish landed and sold by auction at the market of Kralingsche Veer, near Rotterdam. We have these figures since 1871, and just to show you the importance of this auction, I give you the following summary:

Period.	Total number.	Annual average.
1871–1907 (37 years)	1,822,000	49,200
1871–1889 (19 years)	1,133,000	59,600
1890–1907 (18 years)	689,000	38,300
1899–1907 (9 years)	230,500	25,600

These figures show a very considerable diminution. We are not to forget, however, that partly in consequence of changes in the natural condition of the river, partly through the influence of the treaty, and partly through the high development of navigation in the lower parts of the river—Rotterdam harbor—the fishing of the so-called large seine fisheries, which means those selling their catches at the said market of Kralingsche Veer, is now by no means as good as it was twenty to twenty-five years ago. In consequence, the percentage of the ascending fish caught in the lower parts of the river and sold at the said market, before that period, was naturally much larger than it is at present. In other words, there is no reason to consider the decline of the Rhine salmon fishery as quite so important as might be concluded from studying the figures of the Kralingsche Veer market alone.

As, however, reliable statistics for the salmon fishing of the whole river are not available, it is impossible to calculate what part of the whole catch is represented by the fish landed at Kralingsche Veer market. It may be 50 per cent at present, it may be a little more, it may be much less. Last year at Kralingsche Veer market 31,000 salmon were offered for sale, and 9,500 more were landed at five other salmon markets in Holland. Still higher up the river in

Holland perhaps a few thousand more salmon were taken. Then comes the German part of the river, and finally that part where the river forms the boundary between Germany (Baden) and Switzerland and where important salmon fisheries are found; but as to the fish taken in the German and Swiss parts of the Rhine no reliable figures are published. Altogether an estimate of 65,000 salmon as taken in the Rhine during the year 1907 remains probably under the actual production. That year was by no means an exceptionally good one—it was slightly better only than the eight preceding years. A catch of 65,000 salmon in such a year gives us the right to say, I think, that, be its productivity no more so great as it was before, "Old Father Rhine" still is entitled to be called an important salmon river.

Now, it is my conviction, and I wish to conclude my little lecture by saying, that the Rhine to a very large extent owes to salmon culture the conservation of this production. The fact that the same river had more salmon before artificial propagation was begun does not disturb that conviction; that was at a time when natural propagation was still flourishing. Since the latter in the Rhine nearly quite belongs to history, only one way to keep up the stock remains, and that is by artificial propagation practiced in the most normal, most natural way.

DISCUSSION.

Prof. E. E. Prince. There is just one question I would like to ask Doctor Hoek, and that is as to the spawned salmon or kelts. How and when are those observed migrating, and what is the view in regard to their suggested destructiveness in salmon rivers, owing to their predacity?

Doctor Hoek. Mr. President, I thank you very much for the opportunity of telling you.

Kelts return to the sea every year, but not in very large numbers. It is true that our fishing is so organized that we catch the fish coming from the sea and not so well the fish coming down; yet at least some of these fish do not come down so very fast, but remain in a certain part of the river for some time, moving perhaps with the tide. We take some kelts every year. Doubtless it will be interesting to you, in the first place, to hear that most of these kelts are taken on the Rhine in Holland in the months of March and April, and not many earlier; in the second place that the sexes are represented in the kelts about as in the ascending fish, but that the males descend earlier than the females; and, in the third place (which I think is most interesting), that very large kelts have never been taken—the largest kelts we know are of the type of the smaller, so-called summer salmon (length 75 to 93 cm.), and do not belong to the big summer salmon or winter salmon. It remains only to tell you that we made some observations on the food found in the stomachs of the kelts, and that it was found to be indeed a very poor food. From what I have seen on the Rhine I must conclude that they are not accustomed to taking food on that river.

FISHES IN THEIR RELATION TO THE MOSQUITO PROBLEM

By William P. Seal

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FISHES IN THEIR RELATION TO THE MOSQUITO PROBLEM.

By WILLIAM P. SEAL.

Some phases of the mosquito problem are extremely simple and easy of solution, but there are others that have not as yet attracted much attention and that, in the opinion of the writer, will not be so easily solved. The class of mosquitoes represented by the rain-barrel wigglers constitutes, with the salt-marsh species, the most of the mosquitoes, and the most pestiferous of them as mere annoyances. The problem of dealing with these is one of simple engineering, filling and draining, with the oil barrel as an auxiliary.

But the *Anopheles* mosquito is altogether in another class and will require a very different and more complex sort of treatment. It is, in fact, to a great extent a separate problem.

Though fewer in numbers than the other mosquitoes, the *Anopheles* is more to be dreaded because of its wary and insidious manner of attack and of its infectious character. It breeds in both quiet and running water, but always where there is ample protection for its eggs and larvæ, among and over masses of aquatic or semiaquatic plants, confervæ, duckweed, lily leaves, drift, floating dead leaves, and débris. And, lying and moving horizontally on the water, so completely does it assimilate with its surroundings in both color and shape that it is only discernible to the sharpest vision, generally only by its movements, which are sidewise or backward on the surface unless seriously disturbed, when it wriggles down into the water.

After a series of observations and experiments covering several years the writer is not convinced that *Anopheles* can be exterminated by any method so far advanced, or without very great difficulty and the use of every available agency. The character and magnitude of the problem are not yet understood. Several years ago, in an examination of Central Park, New York, *Anopheles* larvæ were found to be abundant, though up to that time the locality was supposed to be free from them. They were found in unsuspected places, and not where the other mosquito larvæ were found, and they were found abundantly in other unsuspected places in New York as well. Moreover, although thousands of

dollars have since been spent in the attempt to destroy the breeding places, they are no doubt still occupied, within gunshot of the stately Fifth avenue homes and nearer to the beautiful playgrounds of the park. The same conditions will be found to prevail in every city.

The most prolific source of *Anopheles* supply is the ornamental plant pond, which is becoming one of the most beautiful features of landscape gardening, public and private. These aquatic gardens provide *Anopheles* with habitats closely approximating the conditions it enjoys in nature, with, however, many protective advantages. Waters of this character can not be treated with oils or chemicals without destroying their beauty. Thus it becomes a serious problem how to destroy this pest and yet preserve the beauty of the ornamental plant pond.

Anopheles, as well as all other mosquitoes, have numerous enemies in addition to fishes. All the aquatic beetles and their larvæ (and they are numerous), the dragon flies and their larvæ, the boat flies, the crane flies and their larvæ (and where these latter are numerous few mosquito larvæ will be found), the water skaters, and many others.

The use of fishes for the purpose of destroying mosquito larvæ is looked upon generally as an easy solution of the problem, and numbers of species have been recommended for the purpose, but so far as *Anopheles* is concerned the fishes have been generally useless. It is true that by their presence in the more open spaces they limit the areas in which mosquitoes would otherwise propagate in great numbers, and no doubt they destroy some *Anopheles*, as well as some of all other species of mosquitoes.

All small fishes, whether of the smaller species or the young of the larger kinds, will be found to eat mosquito larvæ with avidity if supplied to them. This fact alone can not be taken as evidence of usefulness in this respect in a natural condition. Nevertheless, there is no doubt that the myriads of small fishes everywhere on the salt marshes and as well in all open waters, salt and fresh, prevent by their presence such a multiplication of mosquitoes as would make life unendurable. In this respect even the most insignificant of the fishes are useful and merit our gratitude.

In considering the usefulness of fishes in this relation the natural habits and characteristics of a species are the only safe guides. That they will eat mosquito larvæ if confined in an aquarium is to be expected. But will they do so in a natural condition? Will they seek for them as food? Stagnant water, where there is an abundance of plant life, affords such a great abundance and variety of larvæ and other low forms of animal life that fishes could hardly be expected to develop epicurean tastes for particular kinds of larvæ. They appear rather to gorge themselves with whatever comes in their way. The

great need is that there shall be enough mosquito eaters to consume all the other food that occurs and all the mosquitoes as well. And this means enormous numbers of fishes. What this involves is yet to be determined. We have no adequate conception of it.

While, as has been stated, all fishes have some measure of usefulness, if only in the way of deterrent effect, there are only a few species likely to be found in waters in which mosquitoes breed, and especially where *Anopheles* breeds. The most important of these are: The goldfish, which are introduced; several species of *Fundulus* (the killifishes) and allied genera; three or four species of sunfish; the roach or shiner; and one or two other small species of cyprinoids. In addition, there are a few sluggish and solitary species like the mud-minnow (*Umbra*) and the pirate perch (*Aphredoderus*), which live among plants. The sticklebacks have been mentioned in this connection, but the Atlantic coast species are undoubtedly useless for the purpose, being bottom feeders, living in the shallow tide pools and gutters, hidden among plants, or under logs and sticks at the bottom, where they find an abundance of other food.

In the salt marshes there are myriads of killifishes running in and out and over them with each tide, while countless numbers of other and smaller genera, such as *Cyprinodon* and *Lucania*, remain there at all stages of the tide. So numerous and active are all these that there is no possibility of the development of a mosquito where they have access. Of the killifishes two species, *heteroclitus* and *diaphanus*, ascend to the farthest reaches of tide flow, but it is a question as to whether they would prove desirable for the purpose of stocking landlocked waters, since they are much like the English sparrow, aggressive toward the more peaceable and desirable kinds. Even *Cyprinodon*, which would seem to be a valuable small species for the purpose, is viciously aggressive toward goldfish and no doubt all other cyprinoids. It is characteristic of all killifishes that they must be kept by themselves in aquaria. They are the wolves and jackals of the smaller fishes.

As a destroyer of *Anopheles* the writer has for several years advocated the use of *Gambusia affinis*, a small viviparous species of fish to be found on the south Atlantic coast from Delaware to Florida. A still smaller species of another genus, *Heterandria formosa*, ranging from ½ inch to ⅞ inch in length for the males to 1 inch or 1⅛ inches in length for the females, is generally to be found with *Gambusia* and is of the same general character. Both of these species are known as top minnows from their habit of being at the surface and feeding there; the conformation of the mouth, the lower jaw projecting, is evidence of such feeding habit. Both are to be found in great numbers in the South in the shallow margins of lakes, ponds, and streams in the tide-water regions wherever there is marginal grass or aquatic or semiaquatic vegetation to

afford them shelter from the predaceous fishes. They are also to be found in shallow ditches and surface drains where the water is not foul, even where it is but the fraction of an inch deep. In fact, if any fishes will find their way to the remotest possible breeding places of the mosquito it will be *Gambusia* and *Heterandria*. And they are the only ones, so far as the writer's observation goes, that can be considered at all useful as destroyers of *Anopheles* larvæ.

To what extent they could be acclimated in northern waters has yet to be determined. They are to be found in the Ohio Valley as far north as southern Illinois, hundreds of miles above tide water, where the climate must be quite severe. In 1905, at the earnest request of Prof. John B. Smith, state entomologist of New Jersey, the writer planted about 10,000 *Gambusia* and *Heterandria* in New Jersey waters. Some 8,000 were planted in one locality which was thought to afford very favorable conditions. In 1907 Mr. Henry W. Fowler, ichthyologist of the Academy of Sciences of Philadelphia, and author of "Fishes of New Jersey," found considerable numbers of *Gambusia* in the vicinity of Cape May, some 90 miles from where the plant was made. This opens up a very interesting question. Mr. Fowler contends that *Gambusia* should be considered as indigenous to New Jersey. Very strong arguments to the contrary can be advanced, but the question is not of importance in connection with this paper, except that it either gives a farther northern range to the species or that, on the other hand, it shows the possibility of introducing them.

The writer has come to the conclusion, after many experiments in small ponds, that a combination of the goldfish, which is ornamental and useful in the open water, the roach or shiner, which is a very active species, two small species of sunfish, which live among plants, and the top minnow would probably prove to be more effective in preventing mosquito breeding than any other fishes. The goldfish is somewhat lethargic in habit, and is also omnivorous, but there is no doubt that it will devour any mosquito larvæ that may come in its way or that may attract its attention. The one great objection is that it grows too large and that it is cannibalistic, so that when a pond is once stocked with large goldfish the number of young to survive will be small.

The roach is probably the most widely distributed and abundant of all the small fishes except the cyprinodonts. It is a very active fish, always ranging about in search of food.

The two small species of sunfish, of the genus *Enneacanthus*, are very widely distributed. They live wholly among plants and feed upon larvæ of all kinds.

The top minnows are foragers always on the move in the search for food, skimming over the tops of plants with restless energy.

All of the above-mentioned species are among the most abundant wherever found. If the range of the top minnows can be extended north it will prove to

be a valuable aid. They are quite prolific, throwing off young to the number of perhaps 10 to 20 at intervals of about a week from April to October. The young of May will be breeding by July or August the same year, thus giving a second generation in one summer.

But notwithstanding all that has been said, it is a question in the mind of the writer whether any combination of fishes will prove effective as against the *Anopheles* genus of mosquitoes under present conditions of growing ornamental aquatic plants. There must be a change in the construction and management of the water garden. As these are under the charge of intelligent men, it is only necessary that the problem should be understood and that the laws should compel the eradication of *Anopheles* and provide for an espionage over the places where it breeds. But until some organized branch of the state governments takes up an investigation of this phase of the problem in a comprehensive manner nothing will be done. The magnitude of the task is not yet comprehended. It is quite possible that all of the beautiful masses of aquatics can be grown on mud alone without destroying their ornamental character, leaving the large open ones to the water in such a way that the fishes can do their work easily. In the great wild areas of swamp and stream aloof from human abodes the problem is more serious and will tax human ingenuity, but here only the hunter and fisherman are concerned.

At present the attitude of the public mind toward suggested means of exterminating mosquitoes is good-naturedly tolerant but incredulous. And while the children are being crammed with Greek, Latin, and geometry they do not learn how to prevent the breeding of mosquitoes about their own homes or how properly to screen the houses in which they live. It is a lamentable fact that even where mosquitoes are most numerous and virulent not one house in a hundred, it is safe to say, is mosquito-proof. There is an old saying that "What is everybody's business is nobody's business." Practical work to be effective must be somebody's particular business. Local boards of any kind can not easily run counter to individual sentiments and prejudices. It is the State alone that can overcome local stumbling blocks and inspire respect, and it is for this reason that attention is called to the seriousness of this problem and the suggestion offered that it is worthy of the serious consideration of those whose interest is in the waters where mosquitoes breed and abound—the fish culturists and fishermen, represented by the fish and game commissions.

In a paper prepared for the meeting of the American Mosquito Extermination Society in 1905 the writer advanced the opinion that experimentation with and the supplying of fishes for the purpose of mosquito extermination is at least as properly the function of fish and game commissions as that of supplying them in the interests of sport and recreation, which is as much as can justly be claimed for trout culture. The mosquito problem involves both the comfort

and health of all classes of citizens. The desirability of the participation of fish commissions in the work, however, appears to the writer to be a question that can only be settled by submitting it to those who would be most nearly concerned with its practical operation, those engaged in fish-cultural work and who have at their command the necessary equipment and knowledge.

It may be argued that the study of the mosquito problem should devolve exclusively upon the agricultural departments. In 1900 or 1901 this question was suggested by the writer, and the Commissioner of Fisheries then decided that the work properly belonged to the entomological division of the Agricultural Department. At first thought this seems a logical conclusion; but when we come to realize fully the magnitude of the task one is compelled to conclude that its accomplishment will require the combined efforts of all the available resources of the States and probably of the National Government.

The fish and game commissions have in their service a body of men whose duties include an espionage of both the land and waters of the States. By enlarging their powers and authority there is already available a capable organization which needs only efficient direction and support to accomplish great practical results in this direction.

There is another side to the question. The fish and game commissions do not have to the extent that they should the sympathy and support of the public in general, the prevailing idea being that they represent the interests of the sportsmen—gunners and anglers. And from this class alone there should be a vigorous support for such a development, not only because of the promise of greater comfort in their outings, but also because of the added popularity it would most surely give to the work of fish and game commissions and to legislation affecting the waters. If fish culture is to be progressive it must enlist the sympathy of all classes of citizens. It must justify itself by its usefulness. Those engaged in it and in fish and game protection should welcome every opportunity to broaden the scope of fish work. There should be a desire to extend its popularity by enthusiastic support of any line of investigation or work which will benefit the public at large. There is now a precedent in the action of the United States Bureau of Fisheries in collecting and sending fishes to Hawaii for the purpose of mosquito destruction, and there is no reason why the fish and game commissions with their trained experts should not cooperate in absolute harmony with the divisions of entomology, thus avoiding the creation of dual functions in state work.

FOODS FOR YOUNG SALMONOID FISHES

By Charles G. Atkins

Superintendent U. S. Fisheries Station, East Orland (Craig Brook), Me.

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908, and awarded the prize of one hundred and fifty dollars in gold offered by F. M. Johnson for the best demonstration of the comparative value of different kinds of foods for use in rearing young salmonoids, taking into consideration cheapness, availability, and potentiality

FOODS FOR YOUNG SALMONOID FISHES.

By CHARLES G. ATKINS,
Superintendent United States Fisheries Station, East Orland (Craig Brook), Me.

In laying out schemes for the feeding of Salmonidæ, as well as most other fishes, it is to be borne in mind that they are by nature dependent for nourishment on living animals. Any departure, therefore, from a live-food regimen must be regarded as having the presumption against its entire suitability; and the general experience of fish culturists tends to the conclusion that even so slight a departure from nature as the substitution of the flesh of mammals for the natural food is followed by deterioration in some of the most important functions of the fish.

Perhaps the function most seriously affected is that of procreation. It has been found that fishes which have been reared on mammal flesh in artificial inclosures do not produce offspring of normal vitality and vigor, and while the possibility of there being other important factors in the case has not yet been disproved it is the consensus of opinion that the deterioration observed is due mainly to the unsuitability of the food. The view taken of this matter by the best German authorities is well expressed in the concluding chapter of a serial treatise on the feeding of salmonoids by the editor of the Allgemeine Fischerei-Zeitung, January 1, 1907, as follows:

> Assuming that the fishes grown in a wild natural state have the healthiest offspring, it follows that for breeding fishes under all circumstances live natural food is the most suitable. * * * There is a large list of fish breeders who reject wholly the feeding of breeding fish and for egg production use wild fish only. For brook trout this is beyond doubt the correct standpoint, and it would be also for the rainbow and American brook trout if we could get wild fish enough to supply the demand for eggs and fry. As, alas, we can not get them, whoever wishes to breed these fishes must of necessity resort to artificial feeding of breeders.

The experience of American fish culturists will support this view.

Under these circumstances it behooves us to look for food supplies as near to nature as possible, and a conviction that duty leads in this direction has been the inciting motive to the efforts at the Craig Brook station to produce some living insect food which could be substituted for the chopped liver and lights from slaughterhouses and the flesh of old horses, which have been the main dependence thus far.

THE LARVÆ OF FLIES.

The experiments at Craig Brook have included a considerable list of insects and crustacea, but the most attention has been given to the larvæ of flies, especially of two species of flesh fly, the bluebottle fly (*Calliphora erythrocephalon*) and the green flesh fly (*Lucilia cæsar*). During some eight years this work was made especially prominent and on a scale sometimes equivalent to the feeding of as many as 100,000 fingerlings wholly on this food. In most cases there was a mixed ration of fly larvæ and chopped meat, but the exclusive use of the larvæ here and there affords data for definite and accurate statements of the comparative influence of the two regimens on the rate of growth, which is as far as data now available enable us to go.

The methods of the work may be thus briefly described:

Some kind of fresh animal matter, mainly slaughterhouse refuse and such parts of animals slaughtered or dressed at the station as were not available for direct feeding, were exposed to the visits of the flies, and, when well stocked with eggs, placed under the shelter of a building protected as far as practicable from marauding insects, such as carrion beetles, in specially constructed boxes, in which the larvæ assembled themselves when fully grown in masses conveniently handled. These were fed to the fish in troughs or ponds, mainly in wooden troughs about 10 feet long and 1 foot wide, sometimes in conjunction with other articles and sometimes alone, but in the latter case the fry had gone through a preparatory stage of feeding on chopped liver or similar meat for a few weeks, during which they had attained sufficient size to swallow young larvæ. The fry generally began to take food about June 1. The feeding of larvæ was generally begun early in July and was continued till some date in October, when the fish were counted, weighed, and liberated. The weighing was done in this way: A pail of water was suspended from a spring scale and its weight accurately noted. Then 200 fish or less by count were held in a soft net until the water had drained from them, when they were turned into the pail of water and the increase in weight noted. In case of very small numbers, each fish was weighed separately on a very delicate balance. The record is therefore very accurate. Sometimes the larvæ were given alternately with chopped meat, and in many other cases there were changes sufficient to forbid deductions as to the influence of the food on the growth of the fish, but here and there are cases giving positive evidence of importance.

In 1888 the record shows that lots no. 10 and 11 were fed through the season exclusively on chopped meat of various kinds (almost wholly butcher's offal), and lot no. 13 was fed on larvæ exclusively after June 2. In detail the treatment of the several lots was as follows:

Lot 10, Atlantic salmon numbering (June 7) 1,196, kept in one trough and treated as follows:

June.—Fed until 9th somewhat irregularly on wild live food collected from pools and other open waters; from 9th to 30th on chopped meat 2 to 4 times daily; mud baths on 5 occasions; cleaned daily.

July.—Fed chopped food 4 times daily the entire month; mud baths daily till 29th; cleaned daily.

August.—Fed chopped food 4 times daily; cleaned daily.

September.—Treated as in August, but on 29th transferred to a 5-foot white varnished trough outdoors.

October.—Treated as in September until the 17th, when they were counted.

The losses by death in lot 10 from June 18 to October 17 were 611, leaving 585[a] survivors, which were found October 20 to average in weight 30.66 grains (199 centigrams).

Lot 11, Atlantic salmon, numbering (June 7) 1,195, was treated almost exactly the same as lot 10, the points of variation being quite unimportant. Counted October 17 and weighed October 23. There were 538 survivors, and their average weight was 26.83 grains (173 centigrams).

Lot 13. Atlantic salmon, numbering (June 7) 1,864; treatment as follows:

June.—Kept in 2 troughs; fed on entomostracans and insects till June 9, after that chopped meat, 6 times daily; mud bath 3 times.

July.—Fed on liver until 3d, on which day feeding of larvæ was begun; mud bath daily until 29th; cleaned daily.

August.—Fed fly larvæ 6 times daily (with some irregularity); cleaned every other day.

September.—Treated as in August.

October.—Treated as in August until 23d, when counted and weighed. The 1,447 survivors weighed on the average 43.84 grains (284 centigrams).

It will thus be seen that the fish fed on butcher's offal attained a mean weight of 30.66 grains (199 centigrams) in one lot, and 26.83 grains (173 centigrams) in the other lot; while the fish fed on fly larvæ attained a mean weight of 43.84 grains (284 centigrams), a difference of 53 per cent in favor of the larvæ regimen.

A similar comparison between several lots of landlocked salmon reared the same summer shows a slight difference in favor, also, of the larvæ regimen.

The record for 1891 affords data for the following tabular statement, which exhibits the results obtained from the feeding of 39 lots of Atlantic salmon in wooden troughs of the standard size, all treated alike except in the matter of food. Butcher's offal was given to 14 lots of them through the entire season and the other 25 lots received fly larvæ exclusively from June 22 to the date of counting and weighing, which was from October 15 to October 29.

[a] This heavy loss in numbers was the result of an epidemic that attacked the fry in June, irrespective of the food or special mode of treatment. Of the total mortality in lot 10, there were 561 deaths in June, 45 in July, 3 in August, 2 in September, and none in October.

TESTS OF FISH FOOD AT CRAIG BROOK STATION, SUMMER OF 1891.

Fed on chopped meat the entire season.					Fed on fly larvæ from June 22 to October 29.				
Lot no.	Date of weighing	Number of fish.	Total weight.	Average weight.	Lot no.	Date of weighing.	Number of fish.	Total weight.	Average weight.
	1891.		Lbs. oz.	Grains.		1891.		Lbs. oz.	Grains.
283	Oct. 15	1,844	11 3	42.47	279	Oct. 15	1,387	10 1	50.78
284	Oct. 15	1,833	10 11	40.81	280	Oct. 15	1,870	13 13	51.70
285	Oct. 15	1,840	11 2	42.32	281	Oct. 15	1,855	11 11	44.10
286	Oct. 15	1,707	11 4	46.13	282	Oct. 15	1,887	12 15	47.94
287	Oct. 15	1,936	12 4	44.29	297	Oct. 17	1,719	12 10	51.41
288	Oct. 16	1,897	10 9	39.98	298	Oct. 19	994	8 12	60.60
289	Oct. 16	1,472	10 11	50.82	299	Oct. 19	1,707	12 13	53.13
290	Oct. 16	1,394	7 13	39.59	300	Oct. 19	1,864	13 5	49.99
291	Oct. 16	1,815	10 9	40.74	301	Oct. 19	1,571	12 0	53.47
292	Oct. 16	1,801	9 14	38.38	302	Oct. 19	1,629	12 7	53.48
293	Oct. 16	1,813	10 3	39.33	303	Oct. 19	1,646	12 13	54.49
294	Oct. 16	1,824	10 15	41.97	304	Oct. 19	1,767	12 10	50.01
295	Oct. 16	1,798	9 11	37.72	305	Oct. 19	1,691	11 9	47.86
296	Oct. 16	1,574	9 9	42.52	306	Oct. 15	1,284	10 11	58.27
					307	Oct. 15	1,775	14 2	55.70
					308	Oct. 15	1,763	13 6	53.11
					309	Oct. 15	1,628	13 0	55.90
					310	Oct. 15	1,664	13 6	56.26
					311	Oct. 19	1,690	13 2	54.36
					312	Oct. 29	2,048	15 0	51.27
					313	Oct. 29	1,752	14 0	55.93
					314	Oct. 29	1,754	14 2	56.38
					315	Oct. 29	1,814	14 9	56.19
					316	Oct. 29	1,841	14 10	55.61
					317	Oct. 29	1,836	14 6	54.81
Total		24,548	146 6	41.76	Total		42,435	321 13	53.09

Thus the growth of the fish fed with the fly larvæ for about four months exceeded that of the meat eaters by 27 per cent.

For further illustration of the potency of fly larvæ in promoting growth, I will cite the record of 13 lots of Atlantic salmon fingerlings that were fed in 1895, 6 lots on fly larvæ exclusively after July 8 and 7 lots wholly on chopped meat of various kinds. In all other respects the treatment was very closely the same in all cases. The essential facts are embodied in the following table:

TESTS OF FISH FOOD AT CRAIG BROOK STATION, SUMMER OF 1895.

Fed on chopped meat the entire season.					Fed on fly larvæ exclusively after July 8, inclusive.				
Lot no.	Original count.	Survivors in October.	Average weight.		Lot no.	Original count.	Survivors in October.	Average weight.	
			Grains.	Centigrams.				Grains.	Centigrams.
732	4,500	3,425	21.17	137	724	4,000	2,592	62.79	407
733	4,825	3,510	27.76	180	725	4,000	2,813	59.41	385
734	4,825	2,083	29.06	188	727	4,000	3,164	50.75	329
735	4,000	3,001	25.80	167	728	4,000	3,312	53.50	347
736	3,000	2,916	27.91	180	729	4,000	2,929	49.14	318
737	4,000	2,242	34.34	222	731	4,500	2,740	45.51	295
738	3,500	3,119	31.14	202					
Total	28,650	20,296	28.17	182	Total	24,500	17,550	53.62	347

It will be noted that in this statement not only is the general average weight of the larvæ-fed fish 91 per cent higher than that of the meat-fed fish, but the best of the 7 lots of meat fish was materially below the poorest of the 6 lots of larvæ fish.

Other data might be cited, but the above will suffice to demonstrate that for increase of size of young fish, fly larvæ constitute a far superior food to chopped meat. There is reason to believe that the superiority does not end here, but extends to the quality of the growth—that it induces a more healthy condition of the tissues and functions of the fish, among other functions especially those of the reproductive organs. A demonstration of the correctness of this view must, however, wait for further experiment.

Fly larvæ are available for use during the greater part of the year. The blow-fly (*Calliphora*) was found engaged in egg laying as late as November 24. They have been actually used at Craig Brook as early as June and through the autumn and winter and as late in the spring as the month of April. For winter use, meat well stocked with very young larvæ, or even with unhatched eggs, is stored in pits or cellars where development can be retarded or hastened, as may be desired, by changes of temperature. In this way sufficient larvæ were kept during the winter of 1889–90 to feed, exclusively, nearly 10,000 young salmon to April 20, inclusive, with a loss of less than 1 per cent between December and May.

The materials which can be used in this work are sufficiently abundant and accessible in most localities. Among them may be mentioned the refuse of all sorts from slaughterhouses and fish markets, the refuse fish taken by all classes of fishermen, domestic animals dying from accident or old age, especially old horses, etc.

The cost of fly larvæ comes mainly from the labor involved. On one occasion it was found that 40 pounds of horse meat, costing 40 cents, produced 8 quarts, or 16 pounds of larvæ, the material costing thus about 3 cents for a pound of larvæ. It has been found that the mean cost of the labor through an entire season was 7.3 cents per pound of food. Both labor and materials therefore cost 10.3 cents for a pound of larvæ.

One important feature requiring mention is the evil odor generated in the process. However fresh and unobjectionable the materials may be when exposed to the flies, they become, if handled in the usual way, exceedingly malodorous before the larvæ have completed their growth. This is sufficient to forbid the location of the work near human habitations unless some means can be found to suppress the odor. It is claimed that this can be done by the use of smoke. It is also quite possible that the nuisance can be largely abated by the use of earth

as a cover of the meat and the larvæ during the later stages of their growth. In Europe several methods have been brought forward which it is claimed will secure the desired result.

Before leaving the subject of fly larvæ I beg to call attention to the possibility of utilizing for fish food the larvæ of other flies, especially those of the house fly (*Musca domestica*) and of the stable flies (of the genera *Stomoxys* and *Muscina*). Their use would not be attended with the objectionable carrion odor, and it is possible that these or some other species might be grown largely on vegetable materials.

SPRATT'S FOODS.

Several of the Spratt foods have been tried at Craig Brook station, the "fish food" in 1905, the "fibrine fish food" and the "cereal fish food" in 1907. The tests were all made in comparison with chopped hogs' liver.

In 1905, two lots of brook trout fingerlings of the same origin and character were set apart for the experiment, placed in two ponds which were also of precisely the same character, and kept under the same conditions. Each lot numbered August 1 about 20,000. These fish had been fed alike on hogs' plucks and in all respects had been treated alike until the beginning of the test, August 5, from which date one lot (no. 1736) was fed with Spratt's "fish food," while the other (no. 1738), as a control lot, was fed on hogs' plucks, mainly the heart and lights. This contrasted feeding, with otherwise identical treatment, was kept up through August 26, having thus continued twenty-two days, after which the feeding on hogs' plucks was resumed. Each morning the ponds were carefully searched, and each dead fish found was at once taken out and recorded. A few days after the test began it was noted that the mortality was increasing in the lot fed on Spratt's food (no. 1736), while in the control lot (no. 1738) it was diminishing. Thus the Spratt's food lot lost during the first ten days of the test as follows: 0, 0, 3, 4, 5, 6, 11, 11, 13, 10; total, 63; while during the same days the control lot lost 2, 6, 2, 0, 0, 0, 2, 1, 0, 0; total, 13. The disparity in losses continued to increase to the end of the test, and carrying the record forward to the second morning after the close of the feeding we have the following daily losses from August 25 to August 28, inclusive: Of the lot fed on Spratt's food, 38, 69, 76, 148; total, 331. Of the control lot, 0, 0, 0, 2; total, 2. The total mortality from the beginning of the test to the second morning after the abandonment of the Spratt's food regimen was, for the Spratt's food lot, 542, and for the control lot, 21. During the next ten days, ending on the morning of September 7, the deaths were: In the Spratt's food lot, 77, 13, 54, 24, 12, 3, 6, 13, 9, 7; total, 218; in the control lot there were no losses. By the 10th of September the mortality in the Spratt's food lot had so far subsided that from that date to the end of the month there were but 9 deaths, against 1 in the control lot. The

resultant weights of these fish were not ascertained; but the record of losses seems to indicate in a very positive manner that the food tested was quite unfit for salmonoid fish to eat.

In 1907 a test was made at the same station of the merits of Spratt's "aquarium fish food" and "fibrine fish food." In submitting them for a test, the general manager of the Spratt's Patent Company said:

> Our pure-food law guaranty serial number is 1632, and I wish to reiterate the statement I have made previously, that the above-mentioned foods are purely meat, and cereal and meat, respectively, and no preservative, coloring matter, or chemical, etc., whatsoever, has been added to them.

The aquarium food, it was understood, was in part cereal, the other wholly meat. Both of them, as well as the food tested in 1905, were received directly from the company. The fishes selected for the experiment were brook trout, all derived from the same source. Six lots of 500 each were counted out to be fed with Spratt's foods, and several other lots of equal size to serve as control lots, and to be treated in various experimental ways. Three lots of 500 each were to be fed with the aquarium fish food and three with the fibrine fish food.

The experience of 1905 having indicated that it might be difficult to induce fry to take these foods well from the start, the whole six lots were as a preparatory step fed from May 20 to June 30 on finely ground hogs' liver, such as the other fry and fingerlings at the station were receiving. On June 30, therefore, the feeding of the Spratt's foods began, two of the lots receiving the aquarium food and two of them the fibrine food, while the liver regimen was continued with the other two until July 20.

Of the four lots beginning the new food June 30, one was given the fibrine food until October 19 and no other food; another lot was given the same fibrine food and liver on alternate days; a third lot received the aquarium food solely until October 19; and the fourth lot received the aquarium food and liver on alternate days. Of the two lots that continued to eat liver until July 20, one was fed from that date until October 19 on the fibrine food and the other for the same period on the aquarium food. All were fed three times daily.

Of the other lots of trout derived from the same original source, two may be regarded as control lots, numbered respectively, $1939Z^1$ and $1939Z^3$. Both of these, consisting of 1,000 fish each, began to feed May 21, and were fed three times daily through the season to October 9, hogs' liver until the end of July and hogs' plucks from that date to the close.

All of these lots were treated alike, all in troughs fed by water of the same quality, having trough room in proportion to their numbers at the start, the two control lots of 1,000 each having troughs twice as long as the lots having 500 each. Two exceptions were made in favor of two small lots, $1939K^1$ and $1939N^1$,

which had much more room—each a 5-foot trough. The following table is a full exhibit of the lots in the experiment and the principal facts in their history:

EXPERIMENTS WITH SPRATT'S FOODS IN 1907.

Lot no.	How treated—Feeding 3 times daily in all cases.	Original number of fish.	Taken out alive in August.	Close of experiment.		
				Date.	Fish left.	Average weight.
						Grains.
1939K	Liver to June 30; fibrine to October 19	500	15	Oct. 19	4	24.1
1939L	Liver to July 20; fibrine to October 19	500		Oct. 19	14	21.7
1939M	Liver to June 30; then fibrine and liver on alternate days to October 19	500		Oct. 19	466	87.3
1939N	Liver to June 30; then aquarium cereal to October 19	500	100	Oct. 19	4	29.3
1939O	Liver to July 20; aquarium cereal to October 19	500		Oct. 19	37	23.6
1939P	Liver to June 30; aquarium cereal and liver on alternate days to October 19	500		Oct. 19	441	77.4
1939K[1]	Rescued from 1939K August 16, and from that date fed on liver exclusively; kept in a 5-foot trough	15		Oct. 19	5	158.5
1939N[1]	Rescued from 1939N August 16, and from that date fed on liver exclusively; kept in a 5-foot trough	100		Oct. 19	48	154.9
1939Z[1]	Liver to end of July; then liver, hearts, and lights to October 9	1,000		Oct. 9	826	72.6
1939Z[3]	Liver to end of July; then liver, hearts, and lights to October 10	1,000		Oct. 10	768	82.6

Before the end of the first month there developed an abnormal mortality in the lot of trout fed on Spratt's fibrine, the dead picked out on the last seven mornings of the month being as follows: 4, 2, 8, 11, 14, 21, and 34; total, 94; as contrasted with the following deaths in the two large control lots,[a] namely: 2, 0, 1, 1, 2, and 1; total, 7; the rate of mortality being thus, for those seven days, forty-eight times as heavy with the fish eating fibrine as with those eating liver. The heavy mortality in this lot continued till August 16, by which time 480 of the 500 had been picked out dead, the losses in two control lots to that date being only 29 in the aggregate, out of an original 2,000.

The lot receiving liver till July 20 and fibrine for the rest of the season did not develop any excessive mortality until September, but during that month 434 out of the 500 died.

The lot fed on aquarium cereal suffered less, but they too had lost nearly four-fifths of their numbers before the end of August, in the lot taking up this food June 30, and in September an equally heavy loss befell the lot that began this food July 20.

On the 16th of August, as a sort of experimental rescue or secondary control, there were taken out of the first fibrine lot of fish (1939K) 15 of the survivors, and from the first aquarium cereal lot (1939N) 100 of the survivors. These two rescue lots were henceforth fed on liver. The object was to see whether they could, by a return to normal food, be rescued from the mortality that was fast

[a] These two control lots embraced in all four times as many fish as the fibrine-fed lot with which they are compared. The rate of mortality in these control lots was 3½ per thousand, while in the fibrine-fed lot it was 168 per thousand.

sweeping away the original lots. The result was that in the case of the fibrine fish the rescue effected essentially nothing, having apparently come too late; but in the aquarium-cereal lot 48 were saved up to October 19, out of the original 100 taken out in August, or 48 per cent; while of those left to their fate with the aquarium-cereal food only 4 were saved during the same period out of 207, or 2 per cent.

In the cases of the lots fed on Spratt's foods and liver on alternate days, the mortality was not excessive, being only 7 per cent in the fibrine lot and 12 per cent in the other.

It remains to see what effect the Spratt's foods had on the growth of the fish receiving them. As none of the dead fish picked out from time to time was weighed or measured, we can only note the weight attained by the survivors, remarking, however, that the dead fish taken out from time to time were, judging by the eye, never larger than the average of lots from which they were taken, and were generally smaller. All of these weighings were done in the usual way in water, except the smaller numbers, 14 and less, which were weighed singly on a delicate balance. The weighings showed that the 4 survivors of the lot (1939K) beginning the fibrine food June 30 weighed, October 19, on the average, 24.1 grains (155 centigrams) and the lot (1939L) that was given liver till July 20 and fibrine afterwards averaged 21.7 grains (140 centigrams). These are to be compared with the average weights of the fry of the two control lots ($1939Z^1$ and $1939Z^3$), whose average, October 9 and 10, was 72.6 grains (470 centigrams) and 82.6 grains (535 centigrams), respectively; and it appears that the survivors of the Spratt's food regimens had made only from one-fourth to one-third of the normal growth, notwithstanding the fact that they had enjoyed from August 16 to October 19 a greatly enlarged area of trough room and a proportionably very large volume of water.

In growth the fish fed on Spratt's foods with liver on alternate days made a growth fully up to the average of liver-fed fish, the two lots attaining 87.3 grains (565 centigrams) and 77.4 grains (501.6 centigrams), respectively.

One of the most striking of the results obtained was the extraordinary growth of the two "rescue" lots mentioned above—$1939K^1$ and $1939N^1$; the first of these, numbering at the October counting only 5 fish, had by that date acquired an average weight of 158.5 grains (1027 centigrams), and the other, numbering 48, an average weight of 154.9 grains (1003.7 centigrams). These weights are almost unparalleled in the station records of trough-reared fish. It is more than double the weight attained by the fish of the same origin fed through the season on the usual hogs' plucks, as shown in the case of lots $1939Z^1$ and $1939Z^3$. To what shall it be attributed? So far as the comparison is with the ordinary feeding we may safely say that the extraordinary rate of growth during this "rescue" period is the result of the increased space accorded the rescue lots. One of them ($1939K^1$) had, at the beginning of the rescue period, the 16th of August, when there were 15 fish, 44 square inches of trough room per fish, and

at its close, October 19, when there were but 5 fish, 166 square inches, equivalent to 105 square inches for the entire period; and the other lot (1939N[1]) had in like manner the equivalent of 20.4 square inches space for each fish during the entire period; while the two control lots (1939Z[1] and 1939Z[3]) had during the same period a mean of only 1.7 square inches per fish for the first and 1.9 square inches per fish for the other.

It is interesting to note, further, that while the lots of fish that were kept on the Spratt's food regimen until the October count had a generous allowance of space, they failed utterly to receive benefit from it in the matter of growth. Thus the lot of fish fed on the aquarium cereal (1939N), although enjoying through the rescue period a mean of 12 square inches of space per fish against 9 square inches per fish accorded to the liver-fed rescued lot, attained a weight less than one-fifth that of the liver-fed fish; and in the case of the fish fed on fibrine the disparity was still greater, the fibrine fish attaining less than one-sixth the weight of the rescued fish, although the space accorded them per fish was almost exactly the same for the two.

The conclusion to be drawn from the results of these experiments can not be otherwise than this: That all of the commercial foods tried, the "fish food," the "fibrine fish food," and the "aquarium fish food," are entirely unfit for food for young salmonoid fishes. Their value for other kinds of fish is not considered here.

FRESH FISH AND RYE MEAL.

Considerable quantities of fresh fish have been used from time to time at the Craig Brook station, both as material for the growth of fly larvæ and as direct food. In a few instances there have been made exact observations and records, which furnish limited data for demonstrations of their value. In 1907 such data were preserved of a brief trial of the use of fresh fish and rye meal. The subjects of these experiments were 18 lots of brook trout, all from the same original stock, all treated alike in respect to quarters, water, and attendance, except that 6 of the lots contained originally half as many fish as the others and were quartered in troughs half as large. All were fed on chopped hogs' liver until September 5. At that date began the experimental feeding, which continued to October 9 to 12, when the survivors in all these lots were counted and weighed. During this period 6 of these lots were fed on chopped fresh herring, 5 others on herring for ten days and then on a mixture of herring and rye meal, and 7 others, as control lots, on liver until August 1, after which hogs' hearts and lights were added to their fare. Though the period of this experiment was very short, the results seem to indicate that the continuous nourishment with hogs' plucks was the most favorable, that fresh herring came next, and that rye meal stood at the foot of the list. The 7 lots of fish fed on the plucks alone, originally consisting of 1,000 fish each, or 7,000 in all, and num-

bering 5,926 in October, weighed 67 pounds 5 ounces, an average of 79.5 grains (515.1 centigrams).

The 6 lots fed on herring alone, numbering originally in all 3,000 and at the close 2,579, weighed on the average 75.3 grains (488 centigrams).

The 5 lots fed on the herring and rye meal, 5,000 at the start and 4,425 at the close, attained an average weight of 68.3 grains (442.6 centigrams). Though these data indicate, as stated, the inferiority of fish and rye to plucks as promoters of growth, a final conclusion in the matter should await more extended trial.

Though in these experiments the only fish used was fresh herring, it is safe to assume that other fresh fish would be equally potential in nourishing the fish, and the cheapest kinds are no doubt for such purpose of equal value with those of higher cost. The cheapest fish that can be obtained in fresh condition is therefore probably the most desirable, provided it can be easily prepared for use. Herring are especially easy to prepare, as they can be chopped into the desired form without any dressing whatever. This fact and that of their abundance and wide distribution render them perhaps the most available of all species of fish. Their cost is also very moderate, those used at Craig Brook costing 1 cent per pound.

FRESH-WATER SHRIMP, A NATURAL FISH FOOD

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FRESH-WATER SHRIMP, A NATURAL FISH FOOD.

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It has been my belief for years that the greatest benefit to accrue from modern fish culture is to the individual grower, the utilizer of inland waters under control and observation. But the basic need to effect such a result is a natural food of abundance and cheapness, a food that can be grown out of the natural productiveness of the water, a food corresponding to the natural grass on which wild animals feed, to the nectar of the wild flowers which honey bees gather, conserve, and consume. If the agriculturalist reaped no return except from the fertilizer he employed, if there was nothing afforded by the natural elements of the soil, his work would be heavy, requiring pound for pound, so to speak. There is, of course, a natural fertility in the waters which is available, similarly to that of the soil, with the proper agent to take up and conserve it. In the fresh-water shrimp we have an example of such a gatherer and conservator.

Palæmonetes exilipes is indigenous to the coastal plain region of North Carolina. The species is not the so-called fresh-water shrimp *Gammarus*, but a true shrimp, a miniature of the salt-water shrimp and prawn. It is meaty, like those species and the American lobster. In fact, in a time of stress it would sustain man. Though small, it is incomparably larger than *Gammarus*, measuring by actual count 136 to 140 to a fluid ounce or about 2,200 per pint, as taken in the early fall, young and old, with no culling. It is a favorite bait for black bass and crappie, two abundant game fishes of the region, the crappie taking this bait when all others are refused. The angler impales several shrimps upon his hook at a time, and I have observed that they sometimes remained alive for two hours, thus displaying considerable vitality.

The exceeding abundance of fresh-water shrimp may be compared with that of house flies in summer, flying ants on their emergence from the decaying stump, or angleworms in favorable soil. They dwell in masses of water mosses and grasses, and in the region referred to such growth is practically universal on all bottom. Rarely, the shrimps swim in schools in open water, jumping

entirely above the surface when suddenly alarmed by moving objects in or above the water. Ordinarily they are in hiding, to escape their legion enemy, the numerous species of fishes which abound along with them—bass, crappie, sunfish, pike, catfish, yellow perch, and many others. They are captured by a small bait or hand net operated from the bank or from a small boat, but in Sampson County the fishermen use a slat basket instead of the net, the latter clumsy mode of capture suggesting the presence of large numbers. In a place at which I had collected five days before, I dipped up 476 within a space of 4 yards square—114 per square yard. At another place I took 741 in 11 dips, at another 350 at 2 dips, and at another place I gathered 1,000 in thirty minutes' time and at the rate of 900 per square rod. With a 10-foot seine I gathered 1,250 in 3 hauls. Owing to the thick plant growth and the presence of innumerable boughs and leaves of trees, and the small size of many of the shrimps, it is obvious that I gathered but a small proportion of what was there. Hundreds of acres of water in many counties are teeming with this unrivaled natural food of fish. It exists by the millions and by the ton, but scattered, of course.

The fresh-water shrimp abounds in creeks, mill ponds, ponds or lakelets formed by river overflow, and in clay holes or borrow pits along railroad lines where earth was obtained for throwing up railway embankments. In the latter class of locality the shrimp is landlocked and dependent upon rainfall for water supply in holes but 2 to 8 inches deep, unshaded, and subjected to extremes of heat and cold, the thermometer ranging from 10 degrees to approximately 100 degrees Fahrenheit. In summer the water at times approximates or even exceeds 100 degrees, and in the severest winters it freezes several inches thick. The overflows from the Roanoke River, which afford as thick, muddy water (from a clay country) as can be imagined in a stream of its size, appear to have no decimating effect upon the engulfed shrimp. While trees grow along the sides of streams and ponds, and largely out in their waters also, their shade appears to contain no elemental saving quality, the productive borrow-pit pools being in railroad rights of way and denuded of all tall growth.

Instead of hibernating or burrowing during freezing weather, the fresh-water shrimp appears merely to seek greater water depths. Here is another similarity to the salt-water shrimp and prawn, which, in North Carolina at least, pass out to sea when cool weather reigns, seeking the deeper water and remaining in it till springtime. In Northampton County, N. C., I know an angler who annually gathers up quantities of fresh-water shrimp and, in a running, open ditch, holds them through the winter for bait.

From the foregoing it is practically certain that the species is adapted to broadcast distribution in the temperate zone of the globe, and capable of becoming a resource of incalculable value. But while I forecast the possibilities with

this food of nature, it is to be considered that ponds and streams which are deluged with sand and gravel from land washing by rains to an extent to bury and obliterate the bottom-plant growth will prove disappointing. I also mention that the fresh-water shrimp can not swim against a strong current.

To determine its power of resistance in any work looking to diffusion of the species, I made experiments in 1896, as an agent of the United States, in transporting fresh-water shrimps over long distances by express, with no attention en route. The results were gratifying.

I found the species extremely slimy, and that "sliming" was a necessary prerequisite in order to hold them in tanks or transport them. The prevalence of slime aided the removal of broken bits of bark, cypress-tree leaves, twigs, and all sediment. An upright tin dipper was immersed in the center of the pan, and all the foreign matter, clinging together from the sticky slime in a coagulated mass, was easily skimmed off, the shrimp bearing off to the sides of the pan and none being caught in the dipper. Siphons and strainers and hand nets were useless, the antennæ of the shrimp, which are of wonderful length, becoming tangled and fatal injuries being inflicted. In gathering captures from the nets the fingers were the sole instrument, though slight wounds were received from the sharp needles about the head of the shrimp.

Experimental shipments were made in 4-quart tin pails, the same in which German carp were then being distributed, the covers being ventilated by means of punched holes. Ten pails were packed in an open crate composed of thin wood strips and the crate cover secured against opening. Each pail was about two-thirds filled with water and contained shrimp as follows: Ten pails contained 150 each, another ten 180 each, another ten 125 each, and yet another ten 150 each, these several lots being turned over to the express company October 7, 9, 12, and 13, respectively, at Halifax, N. C., for delivery at Washington, D. C., 200 miles distant. The water temperature of streams at Halifax was 53 to 55 degrees Fahrenheit, the railroad journey 8 hours, and the lay-over in the warehouse (at night) at Washington 11 hours, a total confinement in pails, without icing, aerating, or other attention, of 19 hours. The losses were, respectively, 2, 94, 15, and 10, or 121 out of the total of 6,050, or 2 per cent. The second lot appeared to have been overcrowded, 40 out of the 94 being dead in one pail. In two pails, containing 100 and 150 shrimp each, shipped October 15, from the same place to the Neosho, Mo., station, and en route 92 hours, there were but 2 alive at the destination; but in four pails, in the cooler weather of November 14, containing 50, 75, 100, and 150, all reached their destination alive except the 150 in one pail, all of which were dead. It was discovered early that the species is quickly responsive to overcrowding; in fact, notably so. When too thick in the pails they spring out of the water and die

while clinging to the exposed surfaces of the metal sides, apparently glued by their own slime.

I have personally observed beef cattle fattened on two exclusive articles, cotton-seed meal and cotton-seed hulls, the animals haltered in the stall till slaughtering day; a profitable commercial accomplishment, doubtless, but producing a kind of beef that I would turn away from, so far removed are the two food articles employed from the usual, natural food of the beef animal. In the nourishing of fish at cultural establishments a number of articles have been utilized which were as foreign to the usual diet of the fish as the cotton-seed products to the beef animal. The angle or fish worm is universally conceded to be a natural food of fish, but the fresh-water shrimp (*Palæmonetes*) is yet a more rational one, and while the growing of angleworms in quantity by cultural methods might be a doubtful investment of time as a fish-food creative process, there can be no doubt that *Palæmonetes exilipes* is entirely capable of being easily and cheaply multiplied, requiring no better accommodations than a typical mosquito hole minus the larger natural enemies of the shrimp—i. e., the native fishes—which the hole might contain.

THE CULTIVATION OF THE TURBOT

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[Translated from the French.]

The question of marine pisciculture has been for some thirty years a subject of important concern to naturalists. The present crisis in marine fisheries and the necessities involved seem to cause an increase of efforts in this direction.

The term marine pisciculture serves to designate either natural pisciculture or artificial pisciculture (piscifacture), both public and private or industrial.

The so-called natural pisciculture is the simple operation of making the young edible fishes hatched at sea enter marine ponds or artificial reservoirs communicating with the sea, there to be fattened and then captured for market when they have attained a commercial size. Practiced for centuries, its development did not demand any previous knowledge of the phenomenon of reproduction of the fishes. But it does demand the realization of natural conditions which are very special as to localities and surroundings, a thing which prevents it from becoming general.

To this pisciculture, rudimentary to a certain extent, may be opposed the so-called artificial pisciculture, or piscifacture, thus named because the eggs and larvæ are obtained in captivity.

Artificial pisciculture may pursue either of two aims: It may be a public enterprise, an undertaking of the government, as a government alone can enter upon such an operation, its aim then the repopulation of the sea; on the other hand, it may be a strictly private enterprise to inaugurate an industry which would pursue the aim of breeding certain edible sea fishes in captivity for profit.

The first attempts at artificial pisciculture were public undertakings; the aim was to attain the breeding of edible shore fishes in captivity, to have the eggs hatch, and to deposit the larvæ at a point on the coast where a decrease of these fishes had been noticed. The young fishes were released in the sea

a few days after they were hatched, before the entire disappearance of the yolk sac and the beginning of feeding by external means. The Government of the United States was the first to interest itself in this question of such important general concern, by founding in 1878 at Gloucester, in the state of Massachusetts, in the vicinity of the great city of Boston, the first public establishment for marine pisciculture. The establishment at Gloucester was soon followed by one at Provincetown, one at Woods Hole, and one on the steamer *Fish Hawk*. In 1883 Norway followed the example of the United States and created the establishment of pisciculture at Flödevig. In 1889 the Government of Newfoundland founded the establishment of Dildo and, lastly, in 1894, Great Britain founded, thanks to the Fishery Board of Scotland, the establishment of Dunbar. These various establishments gave each year to the sea several thousands of cod, plaice, and even turbots, hatched in captivity; it must nevertheless be said that it was never possible to obtain at Dunbar, the only establishment where the replenishing of coastal waters with turbots was attempted, any natural hatching of this fish, and that it was always necessary to have recourse to artificial stripping and fertilization as practiced for the fresh-water fishes.

It is not our aim to discuss, after so many others have done so, the question of the real utility of marine pisciculture for the replenishment of the sea. Let us merely remember from the experiments of our predecessors this very important fact: It is due to their efforts that at the present time we have been able to obtain natural spawning in captivity and the hatching of eggs of the greater number of edible coastal fishes having pelagic eggs.

For some twelve years French naturalists seem to have devoted themselves to private or industrial artificial pisciculture. In other words, the work done to-day is an attempt at the entire process of breeding edible fishes from the egg until they reach a commercial size, to create thus a real industry which may in future become an actual source of riches. The first step in the new direction was made by Mr. Edmond Perrier, Director of the Museum of Natural History, Member of the Institute, and director of the maritime laboratory of St. Vaast-la-Hougue, who has the great merit of having been the first to appreciate the importance of the problem and to establish at his laboratory a complete equipment for industrial marine pisciculture.

It will be remembered that without any thought as to its industrial value and for purely scientific purposes, Meyer had been breeding the herring since 1878; at Flödevig young cods were bred, at Plymouth young flounders, and at Concarneau young bullheads; at Dunbar, Harald Dannevig had succeeded in breeding young plaice. In addition to the fact that the industrial point of view was entirely overlooked in these experiments, species of small or no commercial value were experimented upon.

Before attempting marine pisciculture it is necessary to ask oneself what are the fishes for which such experiments would be practically profitable. It is evident that migratory fishes, or those living in depths the natural conditions of which we can not offer them in captivity, are to be eliminated. Moreover, before attempting the breeding of nonmigratory fishes of commercial value there is a certain number of questions which ought to be answered: (1) Is the fish in question of sufficient commercial value to render its breeding profitable? (2) Is its growth in captivity sufficiently rapid, and is the cost of bringing it to its commercial size disproportionate to its market price?

In the last analysis it will appear that among the fishes inhabiting our European waters there are only four species which are profitable objects of marine pisciculture. These are the sole (*Solea vulgaris* Quensel), the turbot (*Rhombus maximus* Linnæus), the umbrina (*Labrax lupus* Cuvier), the surmullet (*Mullus surmuletus* Linnæus). According to Cunningham, the turbot at the age of two years is from 28 to 38 centimeters long, and reaches 60 centimeters at the age of four years. As to the sole, it reaches only 23 centimeters at the age of two years.

Of all these various edible fishes, the most profitable from the point of breeding is the turbot, on account of its high price, its particularly rapid growth, its prodigious fecundity (the turbot yields about 9,000,000 eggs per year) and, lastly, its hardiness and the ease with which it may be fed and fattened. Unfortunately, however, this species is the one the artificial reproduction of which presents the greatest difficulties, as was justly observed in 1905 by Fabre-Domergue and Biétrix, whose researches in this line go as far back as 1896.[a] It must be remembered that no natural hatching of turbot could be accomplished at Dunbar and recourse was had to artificial methods of stripping and fecundation, as for fresh-water fishes.

The problem of industrial marine pisciculture must necessarily traverse two stages before reaching complete realization—a preliminary and purely scientific stage, and a final and really practical stage.

The scientific success of the problem seems to consist in hatching a reasonable number of young fishes and keeping them in the laboratory beyond the critical stage. (As defined by Fabre-Domergue, the critical stage begins when the umbilical vesicle is entirely absorbed and the young fish begins to look for food among its surroundings.) Practical success consists in keeping a considerable number of fishes until they acquire such condition that the operation may be really remunerative. It is evident that before attempting the study of the second feature of this problem the first must be solved. It is only when the

[a] Fabre-Domergue and Biétrix: Le developpement de la sole, 1905. Travail du Laboratoire de Zoologie maritime de Concarneau.

first stage shall have been passed that it will be legitimate to inquire whether the results obtained in the laboratory may or may not be repeated on a larger scale, i. e., to practical purpose, with perhaps a somewhat different technique. Practical marine pisciculture, the origin of which does not date further back than twelve years, is as yet in its scientific period.

The two principal difficulties involved in the solution of the scientific problem are the following: (1) The obtaining in captivity of natural and normal hatches in as great numbers as might be desired, and the determination of the conditions of these hatches. (2) The feeding and the preservation of a reasonable number of larvæ beyond the critical period and under conditions such that the experiment may be repeated. As has been justly observed by Messrs. Fabre-Domergue and Biétrix (op. cit.), the incubation, hatching, and preservation of the larvæ until the beginning of the critical period do not present any difficulties.

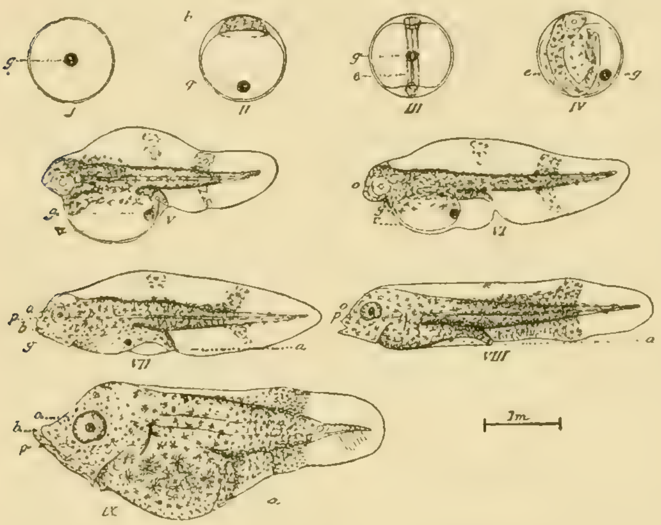

FIG. 1.—Early development of the turbot. I, Fecundated egg; II, egg with blastoderm, III, egg with embryo, not pigmented, IV, egg with pigmented embryo; V, larva just after hatching; VI, larva with vitellus about half resorbed; VII, larva with vitellus almost entirely resorbed; VIII, larva in critical period, vitellus just resorbed; IX, larva at end of critical period. *g*, Oil globule; *b*, blastoderm; *e*, embryo; *v*, vitellus; *b*, mouth; *a*, anus; *o*, eye; *p*, axis of insertion of pectoral fin.

In the laboratories of pisciculture in America, Norway, and England the question of hatching in captivity has been solved for the plaice and for the cod, but could not be solved for the turbot, the only marine fish truly interesting from the point of industrial breeding. The passage through the critical period had not been attempted for any species in laboratories here cited, because the fishes were deposited in the sea before the beginning of this period. The principal object of practical marine pisciculture in recent years, then, in Europe at least, has been to obtain normal hatches of turbots in captivity and to carry their larvæ past the critical period.

It was at the laboratory of St. Vaast-la-Hougue that numerous normal hatches of turbots were obtained for the first time by A. E. Malard in 1898.[a]

[a] Malard, A. E.: Sur le developpement et la pisciculture du turbot. Comptes rendus de l'Académie des Sciences, Paris, 17 juillet, 1899.

In 1904, L. Dantan,[a] repeating these experiments, obtained an identical result at the same laboratory. In both cases the hatching took place normally, but unfortunately all the larvæ died a few days later, not being able to survive the critical stage. Thus only the first part of the problem was solved.

In 1905 Fabre-Domergue and Biétrix (op. cit.) published their memoir on the development of the sole. No hatches of turbot or sole could be obtained in the laboratory of Concarneau where these authors operated. Fabre-Domergue and Biétrix were obliged painstakingly to collect eyed eggs of the sole in the sea. But they were able to bring a small number of individuals far beyond the critical period. For the sole, at least, the second part of the scientific problem was realized. In 1905 Malard and Dantan, who had obtained normal hatches of the turbot, had not been able to carry their larvæ past the critical period, and Fabre-Domergue and Biétrix, who had not been able to obtain hatches, had carried the sole through the critical period. With the turbot, rearing past the critical period had not been accomplished.

In the course of 1907 we were more fortunate at the laboratory of St. Vaast-la-Hougue than in 1898 and in 1904, and succeeded not only in making the larvæ live beyond the resorption of the umbilical sac, but in obtaining after this critical period a considerable increase of volume and an important modification of the shape. The conditions under which I obtained these results are the following:

During the month of February, 1907, I procured 10 adult turbots, which I placed in the large hatching basins of the laboratory. These basins, constructed according to the directions of Mr. Edmond Perrier, are three in number. The capacity of the largest is more than 300 cubic meters. They are filled by means of a pump, worked by a windmill, or a gasoline motor when the wind is not sufficiently strong. This pump brings the water to the upper part of the basin. A waste pipe is in the lower part. In the middle is an incomplete trench about the depth of a stair step, made after the design of A. E. Malard, to promote the spawning of the females, which this author found rubbed their abdomens against its acute angle. The basins are covered with a thatched roof and are amply lighted.

Let us note that so far there exists no certain external means of recognizing the sex of the turbots when alive, although many naturalists have endeavored to find it. Nevertheless, taking 12 individuals, there are great chances of having both females and males among them. The only thing to remember is that the fish should not be less than 40 centimeters in length. With smaller individuals there would be a risk of their not yet being mature.

[a] Dantan, L.: Notes ichthyologiques. Archives de Zoologie expérimentale et générale. Notes et revues, 1905.

At the end of a few weeks of captivity our prisoners began to feed. To them were distributed once a week large pieces of plaice at the rate of about half a fish the size of the hand to each turbot. This ration may seem scant, but it was purposely limited, we deeming that too great an abundance of food is not favorable to the functions of reproduction. It is probably to excess of feeding that must be attributed the failure of attempts to make the turbot spawn in captivity. In order to keep the basins free of putrefying food substances we put with our turbots a conger eel and a dogfish long since acclimated to life in captivity. These fishes, well known for their voracity, were employed as scavengers, in which capacity they did good service. Our turbots, in captivity since February, began to spawn in July.

We do not know yet whether individuals that have spawned in captivity and survived one season will spawn the following year. We will not know this until in July next. In any case it does not seem to us very important to know whether it is necessary to keep the same brood stock for one or more years, since fish captured only six months previously had ample time to get acclimated and have given excellent results. Let us add that it seems to us very imprudent to capture breeders only a few weeks before the spawning time. Not yet acclimated, they might exhibit phenomena of ovular retention, which are in most cases fatal.

The first eggs were laid on July 18, and were soon followed by four other lots. The dates of the consecutive spawnings were July 18, 21, 28, 29, and August 3. These lots of eggs numbered thousands and thousands, all normal and normally fertilized. A certain number only were carefully gathered by means of plankton nets and transferred to the incubation apparatus. An essential feature of this apparatus is continuous agitation, which is a very important thing in incubation, keeping the egg free of sediment and thus preventing asphyxiation. Dannevig, among others, at the station of Dunbar had already employed a complicated apparatus which provided continuous agitation.

The apparatus used by us was that of Fabre-Domergue and Biétrix modified, which apparatus is in itself a modification of that constructed by Browne at the laboratory of Plymouth to preserve pelagic organisms alive. It consisted of a receptacle in which a plunging disk rose and fell by means of a special contrivance. In the apparatus of Fabre-Domergue and Biétrix the somewhat violent agitation produced by the vertical motion of the disk is replaced by a helicoidal movement, the disk being obliquely fixed on a vertical rotating axis and thus working like a screw. The apparatus is composed of 4 glass barrels of 50 liters capacity, each supplied with a revolving disk, and the 4 disks are worked by a small hot-air motor of $\frac{1}{40}$ horsepower.

I thought it advisable to make a few modifications in the apparatus of Fabre-Domergue and Biétrix which seemed to me of great importance to the final success. On the thread of the vertical rod carrying the disk I attached above the level of the water, as tightly as possible, a small wad of absorbent cotton to take up and keep off the oil that might come from the wheels above it. I had observed that a small part of the oil could descend along this vertical glass rod and thus reach the water, where it formed a thin layer, the effect of which was hindrance of aeration, causing asphyxiation of the larvæ. Below this wad I placed, upside down, the disk-shaped cover of a small vessel, thus to keep dust from falling into the water, without, however, hindering the circulation of the air. This disk was secured below by a second wad of cotton. I also utilized the lower, lateral, tubular outlet of the barrel to set up a tube within terminating at the top in a funnel covered with very fine silk, to allow the passage of water but not of larvæ. The opening of this funnel was the size of a 5-franc piece, and the flare thus obtained was designed to decrease, as far as possible, the intensity of the current, which, were it too violent, would certainly have carried the larvæ with it. This possible carrying out of the larvæ constitutes a real danger, against which, however, we are still better protected in the apparatus which we have had constructed for our experiments in 1908.

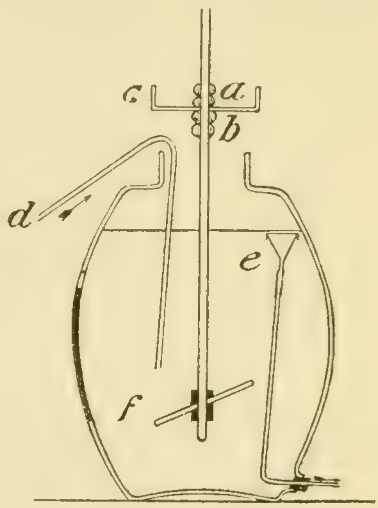

FIG. 2.—Apparatus for hatching turbot (modification of apparatus of Fabre-Domergue and Biétrix). *a* and *b*, wads of cotton; *c*, upturned cover which serves as dust shield, *d*, inflow pipe *e*, outflow pipe with screened funnel entrance, *f*, revolving disk for agitation of the water.

Several times a day part of the water in the barrel was renewed for 10 minutes by means of a siphon, there being in the course of the supply tube a flaring inlet for the purpose of aeration. Several times a day also the bottoms of the basins were carefully siphoned to remove the dead eggs and all other matter that might pollute the water. These modifications, of details only, which we have made in the excellent apparatus in which Fabre-Domergue and Biétrix have been able to carry the sole past the critical stage ought to be considered an indication, so to speak, of more important modifications which will render possible its practical use on a larger scale than from the point of view of experiments only.

The hatching of the eggs took place without difficulty and without hindrance between the sixth and eighth days after spawning. Two or three days after the appearance of the larvæ, without waiting for the complete absorption of the

yolk sac, and following in this the excellent advice given by Mr. Edmond Perrier in 1896, at the Congress of Fisheries at Sables d'Olonne, and a little later, in 1898, by Mr. Fabre-Domergue, we began the feeding of our young larvæ. Their diet was composed of live plankton collected in the open by means of fine-meshed nets, and carefully sifted upon arrival at the laboratory through very fine sifting silk, for the purpose of eliminating the organisms which might constitute a danger by their size or their nature. One distribution of plankton was made every day, and in great abundance. Moreover, the agitation of the water maintained the plankton alive, and the young fry had consequently always in reach a fresh live food as varied as under natural conditions of their life. Toward the fourteenth or fifteenth days the last trace of the sac disappeared, and about the eighteenth or twentieth day the critical period might be considered as passed. The young larvæ had at that period taken the peculiar shape characterized by the widening of the head, and they fed normally.

For the retention of the larvæ after the beginning of the resorption of the yolk sac, i. e., during the critical stage, two things are necessary: (1) Continuous agitation of the water, and (2) appropriate food. Continuous agitation of the water is incontestably very useful in the incubation of the eggs and the normal life of the larvæ up to the time when they begin to feed, but during these periods it is not, as later, absolutely indispensable.

We have, in fact, found at St. Vaast, on the one hand, that the eggs which were left in our hatching basins developed there and hatched normally, and the larvæ did very well until after the disappearance of the yolk sac; on the other hand, the same facts were observed in the hatching aquaria. But what we did not accomplish, and we can not insist too much on this point, was to make larvæ live even a few hours, though offering them plankton, under these conditions after the disappearance of their yolk sac. It is at this time, we believe, with all who have undertaken marine pisciculture, that continuous agitation of the water is absolutely necessary. Without it the young fish is never in the presence of its food, it weakens, falls to the bottom, and dies of hunger.

As to feeding, let us recall that the fry were very precocious, and began to feed even before the complete disappearance of the yolk sac. The objection might be raised that plankton as the basis of food for the larvæ can not be considered for a moment where breeding on a large scale is to be undertaken. It may be said that on certain days storms disturb the sea, and the water being full of ooze and sand, collecting is impossible. We believe that we can say that the period during which plankton will be necessary is precisely during the season of the year in which storms are most rare (from July 1 to September 15, at the latest, for the region of St. Vaast-la-Hougue). Should there be storms,

however, one would always have the resource of small plankton organisms in the pools left when the sea recedes. Moreover, the continuous agitation apparatus will allow us to keep alive a small reserve of plankton to supply the needs of our larvæ for three to four days. And, lastly, one more argument, shall it be considered a priori impossible to breed certain plankton organisms, carefully selected? Continuous agitation apparatus would undoubtedly be suitable for this purpose likewise. The experiments of Bracque have almost solved this question already. I am not opposed a priori to a semiartificial food as, for example, the *Monas dunali* of marshes successfully employed by Messrs. Fabre-Domergue and Biétrix for feeding their larvæ of soles, and it is even possible that this organism might be made to render the greatest service in marine pisciculture. But it is nevertheless most true that it is in the great variety of plankton organisms that we shall find the food necessary for the normal feeding of the larvæ of teleosts with pelagic eggs. I dared not experiment with purely artificial food, advised by others (cheese, shrimp meal, etc.). I believe that rapid putrefaction would occur. I believe, in short, that during the first period the best food would be small plankton organisms, carefully selected.

Let us add that in hatching troughs the temperature of the water ought not to be above 20° C. We have operated constantly at a temperature of from 18° to 20° C. It seemed best to have it from 15° to 20° C. Let us say, further, that during the critical period we lost only 1 individual in 10, a result which might be considered excellent, it seems to me.

What is left to be done in the culture of the turbot? There remains to protect the young larvæ from the end of the critical period to the end of the metamorphosis, since we are sure, and we have often shown by experiment, that there is nothing easier than to fatten young turbots and other pleuronectids, and make them grow. For this purpose it will be sufficient to substitute for the plankton, as rapidly as possible, fish flesh mashed into a pulp, this to be consecutively replaced by larger and larger pieces of fish as the size of the turbots increases.

It remains likewise to carry marine pisciculture from the domain of science to industry, and this is not the least of the work to be done—to determine, in fact, whether the procedure applicable on a small scale in laboratories may be carried on on a larger scale. It is necessary to determine the price of the food required to fatten the fishes bred and to see if this price allows a profit, taking into consideration the market price per kilogram of the turbot.

It is possible that the waste of fishes in the vicinity of great harbors might constitute a valuable resource for industrial marine pisciculture of the future.

RÉSUMÉ AND CONCLUSION.

The results obtained by us at the marine laboratory of St. Vaast-la-Hougue during the summer of 1907 are in brief the following:

(1) After Messrs. Malard and Dantan we obtained natural, normal, and abundant hatches of turbot, a result which had been sought for twenty years in a great number of other marine laboratories.

(2) We were the first to succeed in carrying the larvæ of this pleuronectid through the critical period, the obstacle which hitherto all the naturalists studying pisciculture had been unable to overcome, and which seemed to be the principal rock in the course of marine pisciculture.

(3) Throughout our work the mortality of the larvæ may be said to have been a negligible quantity (about 10 per cent).

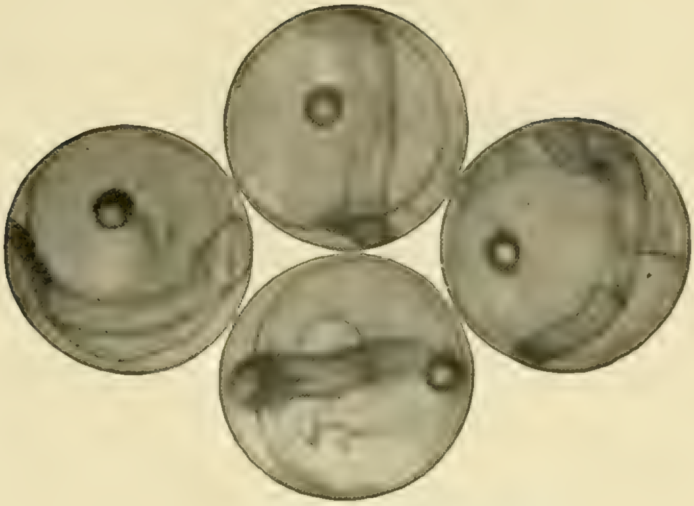

FIG. 1.—Turbot eggs with embryo. Fourth day.

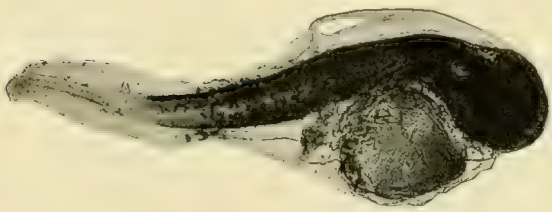

FIG. 2.—Larva with vitellus. Eighth day.

FIG. 3.—Larva with vitellus almost entirely resorbed—beginning of the critical period. Tenth day.

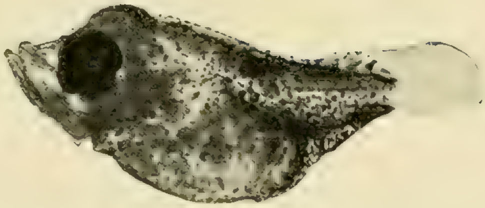

FIG. 4.—Larva a few days after end of critical period. Vitellus has disappeared, abdomen full of food. Shape of fish changed. Twenty-third day

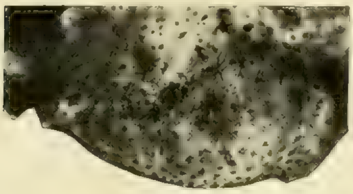

FIG. 5.—Detail of pigmentation of abdomen of above figure.

FIG. 6.—Larva after the critical period (cadaverous shape).

THE TREATMENT OF FISH-CULTURAL WATERS FOR THE REMOVAL OF ALGÆ

By M. C. Marsh and R. K. Robinson

United States Bureau of Fisheries

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CONTENTS.

	Page.
Essential principles of the treatment	874
Susceptibility of fishes	874
Method of administering the treatment	876
Details of continuous treatment	878
1. Determination of proportion of copper sulphate	879
2. Measurement of the water flow	880
3. Determination of volume, strength, and rate of inflowing solution	881
Single-dose treatment	883
Miscellaneous directions and cautions	884
Illustrative and suggested applications of the treatment	887
Further possibilities of the treatment	889
Table of metric equivalents	890

THE TREATMENT OF FISH-CULTURAL WATERS FOR THE REMOVAL OF ALGÆ.

By M. C. MARSH and R. K. ROBINSON,
United States Bureau of Fisheries.

A great annoyance encountered at fish-cultural establishments, or in any ponds where fish are held, is the presence in the water of mossy or slimy plant growths consisting of forms known to botanists as different species of algæ. These appear usually as green or bluish green masses or strands of filaments, which clog the screens of ponds and supply canals and accumulate in the ponds themselves. The clogging of the intake screens or supply pipes endangers the life of the fish by reducing or entirely shutting off the water supply, while the clogging of the outlet screens prevents the water from escaping through the proper channel and allows the pond to fill and overflow, carrying away the young fish; in either case a loss of fish is likely to result, and the trouble of frequent cleaning of screens is inevitable. This sometimes requires the regular attention of the watchman all night or the special services of an extra laborer. The formation and accumulation of algæ within the pond containing fish, especially if there are fry or fingerlings, prevents proper feeding, greatly interferes with the operation of nets in handling fish, and occupies valuable space. The latter tends to crowding and retardation of growth, while frequently fry become entangled in the filaments and strands of the algæ in such a manner that many are lost from this cause alone.

It is true that the green filamentous algæ which are mechanically so annoying are oxygenators in sunlight and often add materially to the amount of dissolved oxygen in the water. In ponds without a rapid circulation they have been observed to superaerate the water with oxygen, and this sometimes occurs in flowing streams;[a] that is, the algæ add oxygen to water which already has absorbed its full or normal supply from the atmosphere. Under these conditions oxygen gas must have been passing slowly from the water into the atmosphere. The objectionable features of algæ, however, usually far outweigh the

[a] Marsh and Gorham: The gas disease in fishes, Report Bureau of Fisheries, 1904, p. 357. 1905.

value as an oxygenator, or as a breeding place for minute animal food for fry, if such it be. A method of eliminating this growth is therefore a great desideratum in fish culture.

Moore and Kellerman,[a] in work conducted with the object of cleansing municipal water supplies of obnoxious algæ, developed a method of treating the water with copper sulphate, finding that this salt dissolved in the water is highly toxic to algæ at a dilution so weak that it may with safety be taken into the human system. The small cost of such treatment moreover, by reason of the cheapness of commercial copper sulphate and the simple means by which it may be used, makes this remedy readily available for practical purposes, and it has for several years now been successfully applied not only for the removal of algæ from reservoirs and ponds, but also in the process of filtration as well. Its possibilities as a useful agent in fish culture have therefore invited investigation with, so far, the results set forth in this paper, concerning algæ as a mechanical annoyance to the fish culturist. Wider application is suggested in certain experiments dealing with bacterial diseases of fish, in which the treatment aims at physiological effect upon the fish themselves, but as yet no definite results in this phase can be reported.

ESSENTIAL PRINCIPLES OF THE TREATMENT.

The efficiency of copper sulphate in the treatment of city water supplies and fish-cultural ponds or streams depends, of course, fundamentally upon the fact that it is by its nature a poison to algæ. Its use for practical purposes depends further upon the fact that it is poisonous in extremely dilute solutions, which are not injurious to most of the higher forms of life and are moreover available by reason of the cheapness of the substance. The first point of consideration in fish culture, therefore, these facts being known, is the susceptibility of the fish contained in the water that is to be treated. If, under given water conditions, the fish are more susceptible than the algæ, the remedy is not applicable. Use can be made of it only where as the proportion of copper sulphate increases the death point to algæ is reached before the death point to the fish. The larger the margin the better, but the method may be used where the margin is very small. The second and remaining consideration is an adequate method of applying the remedy.

SUSCEPTIBILITY OF FISHES.

The chemical reactions by which copper sulphate kills fish are not known. The poison acts through the medium of the water in which it is in solution and in which the fish breathes. The water has other dissolved substances in solu-

[a] A method of destroying or preventing the growth of algæ and certain pathogenic bacteria in water supplies. Department of Agriculture, Bureau of Plant Industry, Bulletin No. 64, 1904.

tion which tend to modify the effect of the copper salt, while the physiological resistance of the fish varies with individual fish and with different broods of the same species. As a matter of fact, fish in general resist the action of copper sulphate better than algæ. The salmonoid fishes have less resistance than any group with which experiments have been made; nevertheless, it has been found in most cases thus far that the necessary margin between the death point of fish and the death point of algæ does exist. Algæ, including some species that cause annoyance, are sometimes killed by much weaker solutions than the weakest known to be fatal to the most susceptible fish, even as weak as 1 part copper sulphate to 50,000,000 parts of water.

The variation of the two important facts, however, susceptibility in individual broods of fish and in the dissolved content of the water, giving rise to wide differences in the quantity of copper sulphate that may be fatal, makes it necessary to determine in each case the susceptibility of the fishes in question in the particular water concerned. It follows that no general formulæ for the proportion of copper sulphate can be stated. Some results actually obtained will be of interest, however, and useful for comparison or to some extent in approximating the strength of the solution which must be fixed more accurately by experiment.

Moore and Kellerman give the following as the number of parts of water to one part of copper sulphate in dilutions which will not injure fish of certain species:[a]

Trout	7,000,000	Catfish	2,500,000
Goldfish	2,000,000	Suckers	3,000,000
Sunfish	750,000	Black bass	500,000
Perch	1,500,000	Carp	3,000,000

These dilutions are presumably close to the death points in the particular water used and with the particular fish experimented with.[b] The trials on which the figures for trout (*Salvelinus fontinalis*) are based show the greatest susceptibility to copper sulphate yet observed for fish. They were made at Cold Spring Harbor, N. Y., and fatal results were obtained at 1 to 6,500,000 with fingerling trout during 24-hour exposures. At Bayfield, Wis., however, adult trout resisted 1 to 500,000 during this period. These are probably extreme cases. In the former algæ probably could not be killed in the presence of the trout, and it is the only case of its kind that has come to the attention of the writers.

[a] Copper as an algicide and disinfectant in water supplies. Department of Agriculture, Bureau of Plant Industry, Bulletin No. 76, p. 11, 1905.

[b] It is of interest to note in this connection that, according to Mr. Kellerman, copper-killed fish are of little use for table purposes on account of the rapidity of decomposition, which seems to proceed more rapidly than with those killed in the ordinary ways. Moreover, the dead fish have usually an unattractive appearance, due to the distention of gills and jaws.

Some laboratory experiments were made at the Bureau of Fisheries with brook trout fry and yellow perch. The trout fry were held in shallow dishes with about one liter of water. The dishes were floated on the surface of cold water to maintain a proper temperature, which was 52° F. or under during the trials. The dilution in the dish was aerated only by contact with the air. In every dilution tested 10 fry were used in each trial; 1 to 500,000 was fatal to most of these fry within 24 hours; 1 to 1,000,000 killed no fry during 48 hours. Intermediate dilutions killed a portion of the sample of 10 during 48 hours. Potomac water was used, having at this time an alkalinity of about 53 parts per million.

Adult yellow perch (*Perca flavescens*) were tried in 10 liter samples of the dilution made with Potomac water held in tall glass jars with only air surface aeration. One perch only was used in each trial. A dilution of 1 to 1,000,000 killed the fish within 24–40 hours; 1 to 2,000,000 was fatal after 48–64 hours in one case, while in another the same dilution was safe during 5 days; 1 to 2,500,000 was fatal after 68 hours; 1 to 3,000,000 was safe during 7 days.

Fingerling large-mouth black bass (*Micropterus salmoides*) proved much more resistant than adult perch. Under the same general conditions as those above described for perch a dilution of 1 to 100,000 killed the fish within 24 hours, while 1 to 200,000, as well as several weaker dilutions, did no harm during 5 days.

Moore and Kellerman in laboratory experiments found that the eggs and fry of large-mouth black bass and very young crappie fry were not injured by 1 to 1,000,000. Carp were found usually to succumb to 1 to 500,000.

Sunfish (*Eupomotis gibbosus*) in a turbid Potomac water dilution were not killed by 1 to 400,000 during 21 hours. Mummichogs (*Fundulus heteroclitus*) were killed by 1 to 750,000, but not by 1 to 1,000,000. The temperature of the dilution in these cases was 78°–80° F..

Silver nitrate has also a very high toxicity both to algæ and to fish. It is probably its expense alone that prohibits its usefulness for some of the same purposes for which copper sulphate is used. Chinook salmon fry about three months old are killed within 48 hours by a solution of 1 part of silver nitrate to 22½ million parts of water, while 1 part to 25 million parts of water is on the border line of safety, and killed a portion only of the several fry used in the test. No substance more poisonous to fishes is known to the writers.

METHOD OF ADMINISTERING THE TREATMENT.

In the treatment of fish-cultural waters with copper sulphate there are, of course, from the mechanical standpoint, two kinds of water to be dealt with, namely, still water and flowing water. For still water the process is comparatively simple, only a single "dose" being required. Such treatment is, however, applicable only where renewal of the water may be dispensed with for the period

during which the remedy is to act. With flowing water the case is more complicated, owing to the necessity of providing a continuing and uniform inflow of the copper sulphate solution adjusted to or varying with the water flow. To do this a convenient method is to dissolve the sulphate in water and allow the solution to flow into the water that is to be treated. The requisites to this operation require some special discussion.

The strength of the admixture (otherwise termed the dilution) in the pond or stream will depend upon four factors—(1) volume of the water flow that is to be treated; (2) volume of the solution of copper sulphate that is to flow into

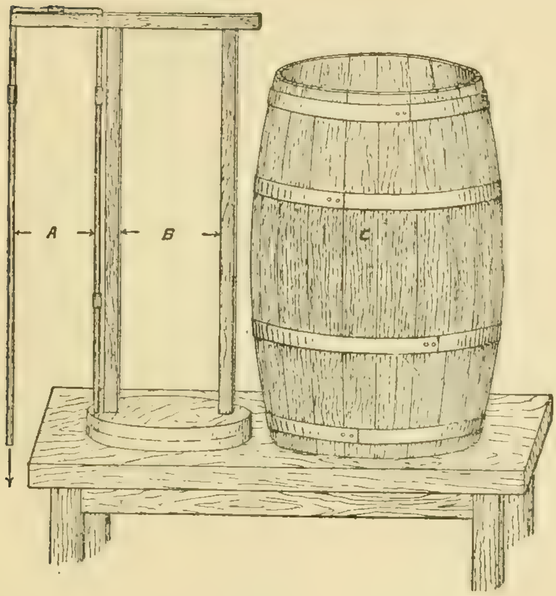

Fig. 1.

Fig. 2.

Note.—In each figure *A* is the siphon, *B* the frame, and *C* the container. The form of the frame is of course not essential, and should be adapted to the container. The illustrations show the glass tubing of much larger size than is necessary or practicable in small siphons. Small tubing is preferable.

it; (3) rate of flow of the solution; and (4) quantity of salt dissolved in the solution. The first factor is fixed and must be ascertained. The other three may be varied as convenient to produce the desired strength of admixture. Any two of these three being fixed, the desired result may be obtained by varying the other one. The delivery of the solution at an unvarying rate into the water flow is perhaps the greatest difficulty and is not to be accomplished by any of the ordinary means of delivering liquids from containers.

If a pipe or tube taps a reservoir containing the solution the head is constantly changing as the level of the solution in the reservoir is lowered. The flow

of solution therefore gradually slows and the concentration in the water treated is constantly falling. If a fixed siphon is used the same difficulty is met. The rate of flow through the siphon depends on the head of the solution, and is therefore never constant. The simplest way to meet this difficulty is the use of a floating siphon, and this is an essential part of the method herein described. A siphon made of glass tubing with rubber connections may be mounted upon a wooden frame and the frame built upon a substantial float. The simplest carpentry suffices to adapt it to almost any shape or size of container. (See Fig. 1.) The frame holds the siphon in such fashion that one arm hangs outside the container and the other in the solution. The outer arm is made the longer, giving such head as is desired. The inner arm passes through the float, ending flush with its lower surface. The frame carrying the siphon floats on the surface of the solution, falling as the level of the latter is lowered. (Fig. 2.) The siphon always has the same relation to this level, and therefore the head is always the same and the flow constant. It is better that the frame be light in weight, relative to the base or float, so that it will float nearly upright, or else guides must be placed at the top of the container to hold the frame in position. This flow of solution may be delivered to the water flow directly or led to it by troughs or any convenient way.

DETAILS OF THE CONTINUOUS TREATMENT.

The metric system is of such great convenience for the measurements and calculations involved that it is used throughout this description, a table for conversion to other units being given. It is worth while to calculate by the metric system, and, if measurements have to be made by other systems, to reduce them to metric units. The reason for this lies both in the advantage of decimal calculation and in the simple relationship of the metric units for weight and volume. For practical purposes 1 cubic centimeter (c. c.) of water weighs 1 gram, and 1 liter (1,000 c. c.) of water 1 kilogram, 1,000 grams, or 1,000,000 milligrams (mg.). Small metric graduates and rules are easily obtained. Weighing will more commonly be by avoirdupois, and conversion should be made. Some method of measuring small volumes should be available. A 1 cubic centimeter volumetric pipette graduated in fifths or tenths is very useful.[a]

For the actual use of fish culturists or others, the details of methods, procedure, and apparatus necessary to apply copper sulphate continuously to waters containing fish for the elimination of algæ or for other purposes, without injury to the fish, are as follows:

[a] Such pipettes, marked in tenths of a cubic centimeter, may be obtained for about 25 cents each from Eimer & Amend, 205 Third avenue, New York City; Arthur H. Thomas & Co., Twelfth and Walnut streets, Philadelphia; or Bausch & Lomb Optical Company, Rochester, N. Y.

1. DETERMINATION OF PROPORTION OF COPPER SULPHATE.

It is first necessary to ascertain with a reasonable accuracy the amount of copper sulphate required to kill the fish which are in the water that is to be treated. Every species concerned should be tested. For this determination it will be sufficient at the beginning to make the test for 24-hour periods in standing water, with controls (i. e., extra or duplicate cans, of the same capacity, containing the same quantity of water and the same number of fish, the only difference between the two being that one holds copper sulphate dissolved in the water and the other does not). Fish cans may in most cases be used as containers for the dilution in which the fish are placed and for the control. Any receptacle large enough to hold a few individuals of the fish to be tested will answer for this. A stock solution, from which to prepare the above dilutions, should be made up in a glass bottle.

The stock solution may be made holding 10 grams of copper sulphate per liter of solution or, in other terms, approximately one-third of an avoirdupois ounce, or 146 grains, of copper sulphate, with enough water added to make 1 quart of solution, is a sufficient equivalent. Each cubic centimeter of this solution will then contain 10 mg. of copper sulphate. If the test is to be made with trout a test dilution of 1 to 1,000,000 may be made; that is, to 10 gallons (37,854 c. c., or 37,854,000 mg.) of water should be added $37{,}854{,}000 \div 1{,}000{,}000 = 37.8$ mg. of copper sulphate, or $37.8 \div 10 = 3.78$ c. c. of the stock solution. (The error in omitting to first remove 3.7 c. c. of water from the 10 gallons is negligible.) This test dilution should be thoroughly stirred. A few fishes should be introduced, not more than the water will readily support for 24 hours or more without artificial aeration, as shown by the control. The function of this extra or duplicate can or container, that of checking the result, is obvious. After a certain amount of experience it may be omitted.

If the fishes all die in the test dilution while those in the control are alive, a new trial should be made, using a weaker dilution. If they are all alive at the end of 24 hours, a new trial should be made, using a stronger dilution. When some of them live and some die during the 24 hours, the death point will have been nearly fixed. The trials should be continued until it is ascertained what is the strongest dilution of sulphate that may be used and yet leave all the fish alive at the end of 24 hours.

Having thus determined approximately the maximum amount of copper sulphate that can be safely used, the treatment may be begun with somewhat less than this amount. It is now necessary to determine the volume of water flow which it is desired to treat.

2. MEASUREMENT OF THE WATER FLOW.

If the flow is small and so delivered that the volume flowing during a few seconds or half a minute may be caught in containers, it may be measured directly. If the flow is too large for this or is through ground pipes, conduits, or ditches in one plane, other means must be resorted to. Technical methods, by the use of current meters, the pitometer, or weir measurements may be used where available. It is intended to discuss here only the simple methods open to anyone without the use of technical instruments.

Where the water is delivered into a pond of reasonably regular shape, it is often easy partly to draw off the water, measure the space thus drawn off, and calculate its cubic contents. The pond may then be allowed to fill up to the original mark and the time required noted. A fair estimate of the flow per minute may thus be readily obtained. If the delivery is below the surface of the water in the full pond a slight error is introduced by the change of head, which is decreasing as the water rises. This error may be minimized by lowering the pond only a few inches, or the least distance that will permit an estimate to be made. Often this estimate may be checked by the following method:

When the flow passes through a completely filled closed conduit the cubic contents of which may be measured, it is sometimes feasible to determine the speed of the flow through this conduit. This may be done by observing the time required for an object to be carried entirely through the conduit by the current, the instant of its entering and leaving this current at each end of the pipe being accurately noted. A block or ball of wood floating through the upper portion of the conduit is not a good instrument for determining the speed of the flow, being apt to scrape the inner surface of the conduit and be retarded; besides, the current is slowest next the surface and fastest in the center. A round, short-neck bottle may be weighted with shot and tightly corked, so that its specific gravity is almost exactly the same as that of water, and when completely submerged it will neither rise nor sink. It will thus remain (in shallow water) at about whatever depth it is placed, for a considerable time at least. If the bottle is of such length that it approaches the diameter of the conduit, say three-fourths of the diameter, it will, after starting properly, float submerged three-fourths of the cross section of the pipe, be thus acted upon by the currents of different rate and give a fair basis for the average speed of the water in the conduit. From this speed and the cubic contents of the conduit the volume delivered per minute is easily calculated.

Flow in open flumes or ditches can easily be measured. Simple modifications of the above method, which it is unnecessary to detail, will readily suggest themselves.

In a case where the writers applied both methods of estimating flow, the lowering and refilling a pond and measurement of speed in a closed pipe, 1,127 gallons per minute were obtained as the result by each method. The exact agreement was a mere coincidence, since these methods can not be presumed to have the degree of accuracy implied, but it indicates that flow may be estimated in a practical way by these means.

The more accurately the flow is known the more rapidly and confidently may the treatment proceed. But it is not necessary to refrain from the treatment even if no measurement of flow is possible. Any person practiced in estimating water flow with some accuracy by the eye may make a minimum estimate. Using this as a basis, a dilution of copper sulphate, much weaker than the susceptibility experiments indicate, may be assumed as safe. The treatment should then be cautiously begun with constant watching of the trout and testing them with food. As a fatal strength of copper is approached they will be thrown "off their feed." While they remain unaffected the strength may be gradually increased until the desired effect is obtained.

3. DETERMINATION OF VOLUME, STRENGTH, AND RATE OF INFLOWING SOLUTION.

The desired dilution and the volume of water flow per minute are now known. The volume of copper sulphate solution, the weight of copper sulphate crystals which are to be dissolved to make this solution, and the volume of flow per minute from the siphon to produce the desired dilution, are to be determined. These three may be mutually arranged in the way which is most convenient. Since it is less easy to change the siphon flow, or to make a siphon which will have exactly a given and predetermined flow, it is better to adjust the volume of solution and weight of sulphate to the fixed siphon flow whatever it is found to be after setting up and starting. The siphon may be made to deliver small amounts, even drop by drop, if desired. A flow of 20 c. c. to 100 c. c. or more per minute covers most cases. The flow should not be so large that renewal of the solution is too often required. If the siphon flow first hit upon is not within reasonable limits it may be increased by lengthening the outer arm or by increasing the diameter of the orifice in the siphon nozzle. It may be decreased by shortening the outer arm.

Having now the siphon flow determined, as well as the dilution and the water flow, the volume of the sulphate solution and the weight of sulphate to be dissolved for one filling of the container of the solution remain to be fixed. It will be natural to approximately fill the container. The volume is thus fixed and the weight of sulphate must be adjusted with reference to it. On the other hand, if only a given weight of sulphate is available, too small an amount to make

the desired solution fill the container, the volume of the solution may be adjusted with reference to this weight of sulphate, instead of vice versa.

The relationships of the five factors may now be given in the shape of formularies. To use these it is better to reduce the water flow per minute to milligrams, though the figures may seem unwieldy. This is done by reducing it to liters and multiplying by 1,000,000.

The proportion (by weight) of the copper sulphate to the water is here designated for brevity and convenience as the "dilution;" e. g., a dilution of 1 to 1,000,000, or 1 : 1,000,000. In formulæ and in computing, the figure expressing the copper sulphate is omitted, as, "dilution" = 1,000,000.

If a is the dilution, and b the water flow in milligrams per minute, then $\frac{b}{a}$ = milligrams of copper sulphate necessary to flow through the siphon every minute.

If c is the siphon flow in c. c. per minute, then $\frac{b}{a \times c}$ = milligrams of copper sulphate which each c. c. of solution must contain.

If z = the number of milligrams of copper sulphate to be dissolved, and y = the number of c. c. of copper sulphate solution to be in the container at the beginning; then

If z milligrams of copper sulphate are to be dissolved, $\frac{z \times a \times c}{b}$ = number of c. c. of solution to be made.

Or, if y c. c. of solution are to be made, then $\frac{b \times y}{a \times c}$ = number of milligrams of copper sulphate to be dissolved.

These expressions are put in words as follows:

Divide the milligrams of water flow per minute by the dilution; the result is the milligrams of copper sulphate necessary to flow through the siphon every minute.

Divide the milligrams of water flow per minute by the product of the dilution multiplied by the siphon flow in c. c. per minute; the result is the number of milligrams of copper sulphate which each c. c. of solution must contain.

Multiply together the dilution, the siphon flow in c. c. per minute, and the number of milligrams of copper sulphate to be dissolved; divide the product by the number of milligrams of water flow per minute; the result is the number of c. c. of solution to be made. But, if the latter has already been decided upon, and the number of milligrams of copper sulphate to be dissolved is unknown, then:

Multiply the number of milligrams of water flow by the number of c. c. of solution to be used; also multiply the dilution by the siphon flow in c. c. per minute; divide the former product by the latter product; the result is the number of milligrams of copper sulphate to be dissolved.

The solution should be made by dissolving the necessary weight of sulphate in a relatively small amount of water and then "making it up" to the necessary volume by the addition of more water. If this volume of water is taken at the beginning the solution will be too large, since the sulphate crystals add to its volume. In some cases the error involved is negligible.

SINGLE-DOSE TREATMENT.

In the application of copper sulphate to large ponds which have a rather small water flow and in which the circulation is therefore sluggish and the same water remains in the pond for a considerable period, the treatment by a continuous flow of solution is not so effective as that by "single dose." The reason is that all waters that support fishes are slightly alkaline, and this alkalinity slowly precipitates the copper from solution. The writers have tried the siphon treatment twice in bass ponds with very little effect, although a much stronger dilution was used than was effective in trout ponds having a much more rapid circulation. In the case of these bass ponds the effect on the algæ was shown only about the intake to the ponds, and did not extend more than 25 or 30 feet from the point where the water entered. The reason for this restriction of the toxic action is taken to lie almost entirely in the prolongation of the time factor. To be effective the sulphate after it is dissolved must come quickly in contact with the algæ. The water moves very slowly through these ponds, and during this time the copper is being constantly precipitated from solution. In the precipitated form it does not impregnate the water uniformly, as in the case of a solution, but is gathered in minute particles which moreover do not have the intimate contact with the algal filaments which is necessary in order to exert a toxic action.

In large sluggish ponds, therefore, it is better to treat them with one dose of copper sulphate, the dilution being calculated to the whole volume of water in the pond. In other words, a given amount of sulphate is added at one time, as if the pond were a body of standing water without a current flowing through it. There is no continuous addition of the sulphate. In applying this treatment the flow may be actually cut off during the process if the fishes will endure this temporary loss of water supply; or an allowance may be made for the water entering during this period; or the inflow may be ignored if the pond is large. With a knowledge of the actual conditions, a choice may be made among these alternatives. In pond culture a constant flow of water to a pond is unusual except for supplying small-mouth black bass. The other species reared by pond culture,[a] chiefly large-mouth black bass, sunfish, and crappie, do not require a constant flow and it is customary merely to supply

[a] See Titcomb, Aquatic plants in pond culture, Bureau of Fisheries Document No. 643, p. 5.

sufficient water to compensate for evaporation, seepage, etc. If the bottom of the pond has considerable springs of water the volume delivered may be taken into account as far as it is possible to do so in calculating for the dilution, unless it is small enough to be ignored.

The first step is to determine the susceptibility of whatever fishes are held in the water to be treated. This will be done in quite the same way as already described under the siphon treatment. Pond-culture fishes will for the most part endure more copper sulphate than trout. The total volume of water in the pond must then be ascertained. The dilution to be used will be indicated by the susceptibility, allowing an ample factor of safety. The milligrams of water in the pond divided by the dilution will give the milligrams of copper sulphate to be used. This will be readily reduced to pounds or ounces or other unit and the amount weighed out. It may be placed in a bag of cheese cloth, burlap, or of other loose-meshed material, and dissolved in the pond by dragging it about at the surface from the stern of a boat.[a] The more thoroughly all parts of the pond are traversed the more uniform the distribution of the sulphate.

If the algal growth is very abundant only part of it may be killed by the first treatment. When there are large masses of algæ all the copper may be used up before the whole of the mass is destroyed. After algæ have grown unchecked in ponds for a long time the growth may mat heavily together, or where there is a current it may form long strings or ropes. These more densely massed bodies of algal growths are less susceptible to treatment. The outside strands may be killed while the inner portions remain alive, being protected by the outer. In such cases as these the dose may be repeated after an interval of time, as a few days or a week. If the pond can once be made free of algæ, it is much easier to keep it so than to kill off heavy growths. It is not always possible, however, to eliminate all growths while fish remain present. The species of algæ vary considerably in their susceptibility to copper, and some may therefore survive on account of their natural resistance to the strongest dilution the susceptibility of the fishes concerned permits to be used.

MISCELLANEOUS DIRECTIONS AND CAUTIONS.

To make the siphon which is to be attached to the float, glass tubing with rubber connections should be used. The smaller sizes of tubing are preferable, that with an outside diameter of 4 to 6 millimeters, or five-thirty-seconds to one-fourth inches, being convenient. The tubing should be bent approximately at right angles to make the turns at the top of the float, the bending being done best by heating in the yellow flame of an ordinary gas jet. The tubing should

[a] Moore and Kellerman, op. cit., 1904.

be held to coincide flatwise with the upper edge of the flame, meanwhile turning slowly on its own axis, until it softens. The flame of a large kerosene lamp or of an alcohol lamp will answer, but will not make as good a bend.

Glass tubing may be neatly broken without cracking by slightly scarring its circumference with a file at the desired point and then, by grasping the tubing firmly with both hands, one on each side of the scar, pulling strongly in a longitudinal direction, making simultaneously a slight stress at right angles. A clean break will occur exactly at the scar.

Nozzles, which are convenient as ends to the outer arm of the siphon, may be made by drawing out in the flame several short pieces of glass tubing and breaking off at some point along the constriction. They may be attached by means of the usual rubber-tube connection. They are not necessary to deliver the flow, and the outer arm may end merely by breaking off sharp; but they give this advantage, that the length of the outer arm, or the size of its orifice, or both, may be quickly changed with their aid, and thus the siphon flow may be quickly and easily varied. For convenience a number of these nozzles may be made, differing sufficiently in length or orifice to give different flows and marked or labeled accordingly. By inserting a given nozzle a given flow may be quickly obtained or a change quickly made. In making these changes care must be taken not to change the length of the siphon arm above the point of attachment of the nozzle if the labeled flow is desired.

It is of course absolutely necessary that there be an intimate mixture between the solution flowing from the siphon and the water flow which is being treated; otherwise a uniform dilution will not obtain. The sulphate will be too strong in places and too weak in others, which may cause the loss of fish and fail to kill the algæ or accomplish the purpose desired. For this reason it is well to deliver the siphon flow at the beginning of the conduit, so that mixing may occur as the water flows. The agitation and mixing at the bulkheads of ponds usually makes a uniform distribution of the sulphate. It will not do to deliver the sulphate at a point where the water inflow to a pond enters quietly with little fall, causing no mixing swirl. It may sometimes be necessary to provide special means for stirring to obtain a mixture.

The stock solution of copper sulphate should not be kept in containers made of ordinary metals. No metals should be allowed in any way to come into contact with the solution. If the flow of sulphate solution to the water has to be conveyed by troughs they should be of wood. Galvanized iron or tin is soon eaten through, and usually can not by painting be sufficiently protected from the action of the copper sulphate. Weak dilutions, however, such as those used for testing susceptibility of trout, may be used in fish cans. The sulphate is not strong enough to attack the metal notably.

It is necessary to avoid leakage from any containers holding the solution in the vicinity of ponds containing fish, since the leak may easily find its way into the ponds.

Special care should be taken in all the calculations and they should be reviewed before the treatment is begun in order to correct mistakes and to see that all factors have been taken into account. The measuring of the water volumes in fish cans and in the solution container, and the weighing of the sulphate for this solution, need but ordinary accuracy. The volume of the stock solution and the weight of the sulphate to be contained in it, however, should be determined with special care and accuracy, since the quantities concerned are small and the error is of greater importance. The scales or balances used should weigh to fractions of ounces.

The difficulty of weighing fractions of ounces in making the stock solution where delicate scales or balances are not available may be obviated by making several times the volume stated, thus using a greater weight of sulphate; or by making the stock solution several times too strong and then properly diluting it. In much the same way portions of the stock solution may be measured in the absence of measures of small volumes. The least conveniently measurable portion should be taken, diluted accurately, the proper portion of the dilution used, and the rest thrown away.

The cost of commercial copper sulphate is about 10 cents per pound in small quantities and about 8 cents in large quantities. It is in the form of crystals, which contain five molecules of water of crystallization. This fact is expressed by the chemical formula $CuSO_4 + 5H_2O$. The weight of these crystals is therefore made up of about 36 per cent water. No account is taken in this paper of this water of crystallization. All references to copper sulphate, or to the strengths of solutions of copper sulphate, or to the dilution, are based upon the crystallized commercial substance consisting in part of water. The actual amount of the anhydrous chemical compound, copper sulphate, actually contained in the solution, in the dilution, etc., is about 64 per cent of the amounts stated. This fact interferes in no way with the calculations used for the treatment herein proposed. In quantitative chemical calculations, however, it is necessary to take account of the water of crystallization.

Clean rain water, or distilled water, is better for making the stock solution than spring or creek water.

The sulphate is best dissolved by suspending it in a burlap or loose-meshed bag near the surface of the water in the container. It then dissolves rapidly and without attention, the heavier solution tending to sink. Stir thoroughly after all crystals are dissolved. If the crystals are at the bottom of the container they dissolve very slowly unless constantly stirred.

The first effect to be seen upon the algæ when the concentration reaches the toxic point is a slight fading of the natural color. When killed the algæ filaments become gray and shrivel markedly, occupying much less space than while alive. The effectiveness of treatment is increased in warmer water.

While trout are considered the most susceptible of the species used in fish culture, there are probably some exceptions, at least under some conditions, as not all species have been tested. Several white suckers at White Sulphur Springs in one instance succumbed to a treatment which did not injure trout in the same waters. Care must be always exercised in the matter of susceptibility.

Great care should be exercised in the manipulation of the copper sulphate salt, the copper sulphate solution, and in the calculations. The substance is not a very deadly poison, yet it may have unpleasant effects upon the human system. Ordinary handling of the salt or the solution will result in no trouble. The siphon should not be started by mouth suction directly on the siphon arm, however. A moderately strong solution taken into the mouth results in a very disagreeable irritation of the mucous membrane and sometimes nausea. Attach a small rubber tube to the siphon nozzle and fill the whole siphon tube by suction; then pinch rubber tube to prevent back flow and detach it; the flow will start.

ILLUSTRATIVE AND SUGGESTED APPLICATIONS OF THE TREATMENT.

AT BAYFIELD, WIS.

The first experiment in the treating of water by this method on a considerable scale was made at the Bayfield station of the board of fish commissioners of the State of Wisconsin. A flow of 1,127 gallons of water per minute was treated continuously for 47 days with copper sulphate so that a dilution was maintained varying from 1:1,250,000 to 1:1,700,000. The dilution was varied at will from time to time for various reasons. Upward of 15,000 brook, brown, and rainbow trout from 2 to 3 years of age were held in this water, and during the treatment no injury was done to any of them. The immediate result of the treatment was the cessation of trouble with algæ in the ponds affected by the flow, a trouble consisting chiefly in the necessity of frequent cleaning of the screens at the outlets of the ponds. The treatment ceased on July 1. Thereafter during the summer the algæ sprang up again, and much attention was necessary to the screens to keep them free of the clogging strands of the filamentous species common in these waters.

This effect upon the algæ was not the purpose sought in this experiment at the Wisconsin station, but was incidental thereto. For several weeks of each summer the brook and other trout at this station are attacked by bacterial infection, the specific cause of which has been described under the name *Bacterium truttæ*. The ravages of this parasite are worst while the temperature ranges

between 50° and 60° F. Copper sulphate even in weak dilution inhibits its action. It was therefore thought that by impregnating the water continuously with this salt, at a dilution harmless to the trout, during the few weeks while the disease usually prevailed, the loss caused by it could be prevented. On account of a break in a conduit and the loss of a large number of the experimental fish from certain ponds, the results of this trial were inconclusive. The total losses in the ponds affected, as compared with those in control ponds, so far as they are of any significance indicate a considerable inhibition of the disease among the brown trout, but the demonstration is not sufficient to set up a claim of practical prevention of the disease in question. The value of this application is for the future to determine. But the particular experiment cited is held to demonstrate the feasibility of long-continued treatment of large volumes of flowing water containing trout with dilutions of copper sulphate of sufficient strength to have an inhibitive effect upon bacterial parasites of fishes and to be at the same time harmless to trout. The expense moreover is well within the means of fish cultural operations. In the case cited it was less than $1 per day. The volume of water treated was unusually large, being more than 1,000 gallons per minute.

AT WHITE SULPHUR SPRINGS, W. VA.

At the United States fisheries station at White Sulphur Springs, W. Va., copper sulphate was applied to the water supply of ponds containing trout for the specific purpose of eliminating troublesome algæ. A floating siphon apparatus was used, similar to that already described, but on a much smaller scale. By 24-hour trials of a few fry in fish cans with copper-sulphate solutions of different strength, the approximate strength which the species would endure for this period and in the given water was ascertained to be about 1 part of sulphate to 3,000,000 of water. The flow of water was estimated at 1,000 gallons per minute. The siphon flow was adjusted so that the above strength was applied to the whole flow. Within 24 hours a marked effect upon the algæ was visible, and a few trout in the raceway which conveyed the water to the ponds were killed. None of the trout (both fingerling and adult brook and rainbow) in the ponds were killed, but the sulphate was not without its effect upon them. It was noticed that the fry either did not feed with their accustomed readiness or refused food altogether. Like cattle and other domestic animals, they were "off their feed." On this account the strength of the solution was readjusted so that a 1 to 4,000,000 flow was maintained in the ponds. In the case of this dilution there was still a noticeable effect upon the trout, as evidenced by their refusal to take food. With young fish—fry and fingerlings—this effect was seen after about 8 hours' application of the treatment. With adult

trout it was not noticeable under 20 hours, but after this period they also refused food. If the treatment was discontinued at the end of 24 hours, both fry and adults would resume feeding with their accustomed vigor within the next 24 hours.

The use of the 1 to 4,000,000 dilution, repeated about once a week for a duration of 8 hours each time, proved sufficient to keep down the algal growths without harm to the fish. The cost of the copper sulphate used in this treatment was at the rate of about 30 cents per 24 hours.

In the summer of 1907 a pond of an area of 0.68 acre and with an average depth of 18 inches, containing 28 adult large-mouthed black bass and several thousand advanced fry, was treated with 4 pounds of copper sulphate in single dose. The treatment was entirely effective in destroying the algæ and, as far as could be seen, without the loss of a fry or an adult.

AT FISH LAKES, WASHINGTON, D. C.

As a part of some joint experiments conducted by the Bureau of Plant Industry and the Bureau of Fisheries two small ponds, each containing a few adult bass ready to spawn, were treated on April 22 with copper sulphate in a dilution of 1 to 5,000,000. The water subsequently became roily, so that observations could not be made on the nesting and spawning bass, but on May 8 a fine brood of bass fry was observed. With the disintegration of the algæ myriads of *Daphnia* appeared. On June 12 a pond of 1.55 acres, with an average depth of 20¾ inches, was treated with 1 to 5,000,000. This pond contained adults, fry, and baby fingerlings of the large-mouth black bass. Careful observations about the pond and of the young fish seined from it daily after the copper was administered showed no harmful effects upon the fish. By June 22 much of the algæ had disappeared, comparatively little remaining. Its disintegration caused the water to impart a very offensive odor when stirred.

This dilution was far weaker than any which, as far as experiments indicate, could in the least harm the species of fish concerned, but it was nevertheless strong enough to eradicate the particular growths of algæ then existing in the ponds.

FURTHER POSSIBILITIES OF THE TREATMENT.

The success of the copper-sulphate method of treating fish-cultural waters for the removal of a mechanical nuisance indicates successful fish-cultural application of the remedy in other directions. The administration of remedies for disease in the lower animals is familiar in the case of the farmer's live stock and other domestic land animals, being the science of veterinary medicine. Upon fishes, however, medical treatment has been practiced but inconsiderably,

notwithstanding the fact that they, too, have been brought under domestication and are subject to all the increased susceptibility to disease that is always consequent upon this more restricted life. The difference is due in part to the relative youth of the science of fish culture and the, so far, relative absence of disease, and in part to the difficulty of administering medicine in the presence of water, from which the fishes can not long be separated. It is obvious, however, that with a remedy that may be applied externally and a process for applying it by means of the water the fish live in, important possibilities are at hand. If copper sulphate, for instance, can be shown to be toxic to the pathogenic bacteria and external parasites of fishes in dilutions yet harmless to the fishes themselves, it will have a much wider usefulness in fish culture than its present application. The only experiments to this end so far undertaken have been inconclusive, but future experiments may be expected to show useful results in this field.

TABLE OF METRIC EQUIVALENTS.

1 centimeter	=10 millimeters=0.3937 inches.
1 gram	=1,000 milligrams (mg.)=15.43 grains.
1 avoirdupois ounce	=28.35 grams.
1 apothecaries' ounce	=31.10 grams.
1 avoirdupois pound	=453.6 grams.
1 fluid dram	=3.70 cubic centimeters.
1 gallon	=231 cubic inches=3,785.4 cubic centimeters (c. c.).
1 cubic inch	=16.387 cubic centimeters (c. c.).
1,000 c. c.	=1 liter.
1 teaspoonful	=1 dram, or 3.7 c. c.

1 c. c. of pure water weighs 1 gram.

Ordinary teaspoons are variable and usually hold more than 3.7 c. c. Medicine glasses graduated in teaspoonfuls (drams) may be obtained at any drug store.

NOTES ON THE DISSOLVED CONTENT OF WATER IN ITS EFFECT UPON FISHES

By M. C. Marsh

United States Bureau of Fisheries

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CONTENTS.

	Page.
Natural impurities in water	893
Poisonous substances	895
Abnormal gas content	898
Dissolved air content of water from a driven well	898
Comparison of means of correction	901
Determination of suitability of water for fish culture	905

NOTES ON THE DISSOLVED CONTENT OF WATER IN ITS EFFECT UPON FISHES.

By M. C. MARSH,
United States Bureau of Fisheries.

NATURAL IMPURITIES IN WATER.

Since fishes are confined to water as their natural habitat, and since water strictly pure scarcely exists naturally upon the earth, they live habitually in water containing a certain amount of foreign substance in solution—in other words, in impure water. There is also nearly always some foreign matter held mechanically. Since these so-called impurities may vary greatly in kind and degree, the study of the reactions which take place between fishes and impure waters of various nature can not fail to be of both theoretical interest and practical importance.

It is profitable to inquire first whether these impurities are merely incidental to the life of the fish as they are to the water, or are essential and necessary. That air dissolved in the water is necessary to support fishes is a matter of common knowledge and observation, for they die quickly if the water is not aerated. It may likewise readily be shown by experiment that water containing dissolved air alone is not sufficient even though plenty of food is supplied. For this purpose, 5 liters of water were distilled through glass apparatus. Contrary to what seems the general impression, distilled water has considerable air dissolved, even immediately after the distillation. A portion of this water from the receiving flask was tested for oxygen during the distillation and contained, at 15° C., 5.48 c. c. of oxygen per liter. Twelve quinnat salmon fry in the sac stage were placed in the 5 liters of water in a glass jar, with a current of air in small bubbles constantly passing to the bottom of the jar and bubbling up through the water. A control was set in exactly the same way, save that Potomac tap water was used instead of distilled water. Three and one-half hours after the beginning of the experiment, the water in each jar being at 14° C., oxygen was determined. The Potomac sample held 7.25 c. c. per liter, the distilled sample 7.09 c. c., each therefore almost air-saturated with oxygen. In the distilled water, after 24 hours, 2 fry were dead, after 27 hours 3 fry, after 37½ hours all were dead. All the fry in the control remained alive. During the experiment the aeration of the control was never greater than that of the distilled sample, and was usually less.

Rain water was tried in substantially the same way and with mummichogs, sunfish, perch, and trout, with the same result. The mummichogs were the most resistant, living 41 hours.

One is led to conclude from this that foreign matter other than dissolved air is a necessary accompaniment of water that supports fish life, and that water can be too pure for fishes. The law is probably of wide application, for low forms of life are known to die readily in distilled water. It is natural to infer also that death is brought about in these cases by some osmotic reactions through the gills, which bring the blood, known to contain various salts essential to the life of the fish, into intimate relation with the water. It is an assumption open to several objections to explain the death as due to the dissolving out of salts or other substances from the blood. Certain obscure poisonous products are believed to be generated in the distillation of water and, conceivably even in rain water, these may have a toxic action on fish. If so, their toxicity is neutralized by contact with many simple substances. It is known that some toxic principles in ordinary water are thus neutralized, as will appear later.

For practical fish-cultural purposes it may be assumed that a certain minimum of dissolved solids is necessary to water before it is suitable for fishes, and no doubt there is also a maximum which should not be exceeded, though a wide adaptability must exist, as some fishes can frequent both fresh and salt water. Where either of these limits lies can not be at present stated. Of course natural waters which contain fishes furnish the safe conditions both as to quantity and quality of these necessary impurities, which are common substances—carbonates, sulphates, chlorids, in combination with calcium, magnesium, sodium, and other common metals. Potomac water had in October, 1905, 240 parts per million; the spring water at the White Sulphur Springs (W. Va.) hatchery had in February, 1906, 484 parts. Neither of these amounts is objectionable so far as known. Many waters have a total solid content below 50 parts per million, and fishes inhabit waters containing no more than 20. It is perhaps true that water with much less solid matter than this would support fishes. It would be interesting to find if possible some natural water fatal to fishes solely on account of its high purity.

It seems that these considerations about the quantity of dissolved solids may become of some practical importance when fish are transferred from one water to another, as from one high in total solids to one low in total solids. Possibly one water may differ so greatly from another in this respect alone that a gradual transfer by slowly mixing the two waters is advisable, in order that the fish may adjust itself from the one to the other. Trout, for instance, do not always thrive after transfer, even when both waters seem admirably adapted to the trout already in them.

POISONOUS SUBSTANCES.

The substances the variations of which have been referred to are substances not harmful in themselves; that is, the action is not a poisonous one. Substances not commonly held in natural waters are usually unfavorable in their action upon fishes, and in some cases there is a poisonous action tremendously greater than with the same substance in higher animals. For instance, copper sulphate is not extremely poisonous to mammals, but 1 part to 6½ millions of water has been observed to kill domesticated brook trout within 24 hours. The fatal amount varies greatly even with the same species in different waters. At the state hatchery at Bayfield, Wis., brook trout were not killed until the concentration reached 1 to 400,000. Some waters precipitate the copper faster than others, but there was probably also a greater resistance to copper sulphate among the trout themselves. General statements of fatal concentrations of such salts must apply only to the water in which the experiments were made and to the fish adapted to that water.

Silver nitrate is even more highly toxic than the salts of copper. In experiments with Chinook salmon fingerlings three months old, one part of silver nitrate to 20 million parts of water was fatal in a few hours and 1 to 22½ million was fatal within 48 hours. With 1 to 25 million the solution is so dilute that about half the number of fish used were killed during 48 hours, the rest surviving; 1 to 30 million and weaker solutions had no recognizable effect.

Many of the metals are poisonous to fishes by lying in the same water with the fishes. Copper is the most active of the common metals in this respect. Twenty square inches in about 6 quarts of Potomac water killed 8 of 10 salmon fry within 24 hours. Ten square inches in the same amount of Potomac water killed 4 of 6 free swimming salmon fry within 2 days and 18 hours and all of them within 3 days and 2 hours. The temperature was never higher than 68° F., and the controls were good.

Zinc, lead, and aluminum are toxic in the order named. Even tin seems to have a very slight poisonous action. In vessels of any of these metals harm to fishes is nearly always prevented by even a slight flow of water. It is when the water is not changed that the injurious action is seen. Iron seems to have no effect. Galvanized iron and lead, and asphaltum and enamel paints all have more or less toxic action, but containers made of or painted with these substances become less harmful with use. Usually considerable time is required before the toxic substance becomes in sufficiently concentrated solution in standing water to have an effect, and this is the reason such containers are often used successfully for transporting fishes. They have, however, been repeatedly identified with certainty as the cause of loss of fish.

Various industrial wastes are of course injurious in sufficient concentrations, but the actual effect of some of these has been exaggerated, perhaps partly because they are sometimes highly colored and of unsavory appearance. Paper-pulp mills which use the sulphite process spend a dark-brown liquor of strongly acid reaction which contains, besides the chemicals used for extraction, the extractive matters themselves, organic compounds of comparatively complex nature. These latter are themselves often toxic to fishes, as well as the extracting agent, and the effluent containing both is presumably always quickly destructive to fish life in its undiluted condition. When discharged into streams it quickly undergoes great dilution, and it becomes of interest to know at what point it is rendered harmless. A sample from Covington, W. Va., at a dilution of 1 to 200 did not injure salmon fry during 2 days. It is evident that tremendous amounts would be required to raise the water of a stream of any size to a fatal concentration. It has been suggested that when wastes containing sulphites kill fishes the loss of dissolved oxygen due to the reducing power of the sulphite contributes to the result by tending to asphyxiation. A sample experimented with by the writer had little or no reducing action on the dissolved oxygen in the water, and it is likely that it kills by its direct action alone.

Other industrial pollutions, such as the wastes of paper-pulp mills using the soda process, tannery wastes, and dye wastes from knitting mills, will kill fishes, but the most toxic of them are made harmless to such fishes as black bass and yellow perch by the addition of a few hundred parts of water, usually 200 parts. Wastes from the manufacture of illuminating gas, however, require some hundreds of thousands parts of water to dilute them to harmlessness. The water soluble substances in bark and in the wood of some trees are capable of killing fishes, but while such products are undesirable in streams the amounts of bark and wood necessary to affect fish in flowing streams are so large that it is not likely that they do much direct damage to fishes by the substances which dissolve from them.

Tobacco ashes have been said to kill trout fry in transportation cans. After trials with salmon fry no effect whatever could be detected unless the fry were in the sac stage and lying on the bottom with the free ash, when they would suffocate from clogging of the gills. If the ash was wrapped in a cloth or if the fry were free swimming there was no effect. It is possible that the ash from other samples of tobacco would give a different result.

Fishes are very susceptible to acid water and succumb to the mineral acids in very weak solutions which scarcely taste sour. Hydrochloric acid kills mummichogs and sunfish when enough has been added to destroy the alkalinity and make about 8 parts of acid per million. Some 40 hours were required for the sunfish. The mummichog or bull minnow is more susceptible than the sunfish.

About 12 parts of sulphuric acid per million kill the same species within 24 hours. According to the degree of alkalinity of the water considerable acid may be added before the water becomes acid in reaction.

This matter of changing the reaction of water is important in connection with some industrial pollutions. An interesting case occurred during the spring of 1905 in the Potomac above Cumberland, Md. A large number of fishes, largely minnows, were found dead and dying along the shore, and still greater numbers were sick and weak and could be picked up in the hand. Twenty-nine miles above Cumberland a paper mill sewers into the river a highly alkaline waste, several tons of lime sludge passing in daily. Shortly below this point Georges Creek enters, carrying an acid waste from the coal-mine regions. It contains free sulphuric acid and salts of acid reaction. The creek water is distinctly sour to the taste and is said to contain no life of any sort. When the two wastes mix at and below the mouth of Georges Creek they neutralize each other, and besides improving the river from a sanitary standpoint permit the fishes of the river to thrive. They must be usually fairly well balanced, since fishes have usually been in some abundance. In October, 1900, on the occasion of a sudden occurrence of dead fishes in the river a sample of water was reported to contain free sulphuric acid, to which the loss of fishes was attributed. On the more recent occasion referred to the water, which was only examined as the fishes were recovering, was not acid, but the alkalinity was reduced, was very low and was rising, and therefore the probability is that the river had just been acid and was recovering its normal alkalinity. It could hardly be expected that the two extensive pollutions mentioned would be invariable in amount, and it can hardly be doubted that the acid occasionally predominates and kills fishes. The acid pollution is by far the more important in its effect upon fishes.

The courts have on occasion held that in the case of coal-mine wastes damages can not be collected nor the mine owners enjoined, since the pollution is a natural one and occurs to some extent independently of mining operations. In the instance cited it would seem that each pollution is the salvation of the river from the other; that the net result is a beneficial one, and that it would be unwise to meddle with either unless it were possible completely to remove both.

Some natural waters have been observed to acquire a selective toxicity by remaining in tin cans for some time. They become, for instance, fatal to rainbow but not to brook trout. During the spring of 1907 some results in this respect of much interest were obtained from the city water of Norfolk, Va. Samples transported in new tinned fish cans were uniformly fatal to fry of the rainbow trout, but had little effect on brook-trout fry. Samples transported in tinned fish cans which had been in use a long time and become rusty on the inside gave contradictory results but were often likewise toxic, though less

markedly so, while samples carried in glass containers had no toxic quality. No toxicity was imparted to Potomac water by repeated and long-continued trials in such cans. The toxic element in the water was not identified, but it is of interest to find that it was destroyed or neutralized by some very simple means. Boiling made the water harmless, and heating to 75° C. greatly reduced the poisonous effect. It was also corrected in large part, sometimes almost completely, by the addition of a portion of either sea water, common salt, calcium sulphate, sodium carbonate, residue from the evaporation of Potomac water, or ordinary earth.

Water brought in fish cans from Newport News, Va., had a similar selective toxicity and was corrected by most of the agents mentioned above and also by the presence of fish in the water, especially by the dead bodies. Thus a sample of this water by standing with the bodies of the fry it had killed became less able to kill other fry of the same species. Shaking and soaking with bone black diminished the toxicity somewhat. These experiments suggest that for aquarium exhibits on close circulation or for the temporary holding of fish in standing water, water which it is dangerous or impossible to use may be made fit for fishes by dissolving in it some of the cheap and easily procurable substances mentioned.

ABNORMAL GAS CONTENT.

DISSOLVED AIR CONTENT OF WATER FROM A DRIVEN WELL.

This well was driven in May, 1906, and is 83 feet 10 inches deep. It passes for most of the distance through clays, which include two strata of water-bearing gravel and sand between the 34 and 52 foot levels, and finally takes water from fine sand and coarse sand and gravel beyond a depth of 80 feet. A 6-inch casing reaches the whole depth of the well and contains a 4-inch pipe through which the water is pumped. The casing is perforated for several feet near the 50-foot level, so that the water-bearing gravel at this level contributes to the supply of water.

The water level in the well stands about 21 feet below the surface of the ground. The electric pump installed was able to lower the level to about 28 feet, where it remained constant. The pump as ordinarily run delivered 24 gallons per minute, but could be made to deliver 32 gallons per minute. The temperature of the water was about 15° C. (60° F.).

It was intended that the water be used in the trout aquariums during the summer in order to avoid the expense of refrigerating Potomac water. On April 11, 1907, the water was turned into an aquarium containing trout. They soon showed marked distress and the water was then shut off. The next day the pump was started again and by delivering part of the flow into a glass jar

it was seen that a continuous stream of minute bubbles of gas was always contained in the water issuing from the well. On dippering the water in the jar a marked white cloudiness caused by very minute bubbles appeared after a fraction of a minute. This cloudiness disappeared after a few minutes and the water became quite clear. On dippering again the same occurrence took place, and this could be repeated several times before the water ceased to cloud upon dippering.

Trout placed in a jar of the water just as it was delivered from the pump were immediately in great distress and within one minute turned over apparently suffocated. If then immediately removed to Potomac water, they revived. Trout placed in the well water after dippering it considerably lived a few hours, but then died. From the behavior of trout in the water and the release of gas from it, it was inferred that the water had a considerable excess of nitrogen or carbon dioxide, or both, and at the same time a very marked deficiency of oxygen. A determination of the oxygen alone showed only 0.2 c. c. per liter of water, while the water was probably capable of taking up from the atmosphere at least 30 times this amount of oxygen. The lack of oxygen accounted for the immediate suffocation of trout.

By various experiments in exposing the water to the atmosphere, such as allowing a slender jet of it, issuing with considerable force from a glass tube drawn out to a small orifice, to impinge upon the center of the bottom of a tall glass cylinder or battery jar laid horizontally, it was found that brook trout would live in the water thus very thoroughly exposed to air. The introduction of air into the water by means of the usual linden wood liberators accomplished the same end provided there was no renewal or flow of water. It was necessary in the case of a large aquarium full of water to let the air current flow for some time before introducing fish in order to give the water a chance to take up enough oxygen to keep the fish from immediate suffocation while the oxygen content was further increasing.

The method mentioned above of breaking up in part into spray a jet of water, even when three air liberators were delivering finely divided air into the aquarium which received the water, did not succeed in air saturating the water with oxygen. That is, it did not fill the water with as much dissolved oxygen as it was capable of absorbing from the air. It raised the oxygen content, however, from 0.2 c. c. to 4.6 c. c. per liter. By cutting off the flow of water and allowing the liberators to run air into the tank full of standing water for some 40 hours in the presence of two yearling brook trout the water then held 6 c. c. of oxygen per liter at 11.5° C.

The water was thought of such interest on account of its peculiar air content and other features that a determination of the nitrogen dissolved was

desirable. Accordingly a number of samples were boiled and the constituents of the gas obtained in this way determined quantitatively by absorption. The following table gives the results for the water just as it is delivered from the well and before it has undergone any appreciable exposure to the air:

TABLE I.—CARBON DIOXIDE, NITROGEN, AND OXYGEN IN CUBIC CENTIMETERS PER LITER OF THE UNTREATED WATER FROM THE ELECTRIC PUMP.

[In all tables the gases are reduced to 0° C. and 760 mm. (of mercury) pressure, and corrected for tension of aqueous vapor. These are the standard conditions for stating gas measurements.]

No.	Date.	Temperature of water.	CO_2.	N.	O.
		°C.			
1	April 28, 1907	15.5	52.8	55.2	0.71
2	1 hour later	15.5	39.8	24.5	0.28
3	April 29, 1907, 11 a. m.	15.5	49.0	24.5	0.45
4	April 29, 1907, 3 p. m.	15.5	35.4	21.4	0.20
5	April 30, 1907, 10 a. m.	15.5	37.5	19.1	0.13
6	April 30, 1907, 3 p. m.	15.75	39.7	21.7	0.06

The carbon dioxide obtained by boiling water shows the amount dissolved in the water as gas and part of that dissolved as bicarbonate salts, since the latter decompose on boiling, liberating carbon dioxide as gas. This is not a satisfactory method of determining carbon dioxide in water, and the figures are included here only because it is necessary to obtain them in order to determine the oxygen and nitrogen. They are not of especial significance. Probably, however, a large part of this carbon dioxide is dissolved as the gas.

The first determination is much higher in each gas than any of the others. There is no satisfactory explanation for this. No. 5 and no. 6 were made after the pump had been working continuously for 24 and 29 hours, respectively, and are to be compared with no. 3 and no. 4, which were made at the beginning of this continuous run. It appears from this that the water does not improve particularly with continued pumping.

Water at 15.5° C. can take up from the atmosphere about 13.7 c. c. of nitrogen and therefore this well water has an excess of about 5 to 10 c. c. of nitrogen, or the normal and proper content has been increased 39 to 79 per cent. This is the largest nitrogen superaeration that has been determined in Fisheries station water, although at Woods Hole an excess of 5 or 6 c. c. in the sea water was experimentally induced. It is known that such an excess is fatal within a day or two at most, to many fishes, and that an excess of 2 or 3 c. c. is sufficient to make considerable trouble. In this well water, however, the effect of the excess of nitrogen upon fishes can not be observed since the deficiency of oxygen

is so great that the fishes are immediately suffocated before the nitrogen has time to cause any symptoms. When the oxygen is increased by aeration, the nitrogen, of course, is at the same time decreased.

The oxygen, as shown by boiling determinations, agrees approximately with that shown by titration, in no case rises to 1 c. c. per liter, and varies from less than 0.1 c. c. to 0.45 c. c. (excluding first sample). This deficiency is probably practically as bad, as far as fishes are concerned, as if the water were absolutely lacking in dissolved oxygen.

COMPARISON OF MEANS OF CORRECTION.

Having thus a water in which the coexisting deficiency of oxygen and the excess of nitrogen were each more extreme in degree than in any case yet met with, it was thought desirable to experiment in correcting it by exposing it to the atmosphere, and to compare methods or devices for accomplishing a thorough exposure. The question of what was the best general method was submitted to Mr. H. von Bayer, the architect and engineer of the Bureau, who recommended flow along sanded and pebbled troughs on a gentle incline as theoretically best adapted to expose and correct small or moderate volumes of water. Wooden troughs were accordingly made under his direction and when finished were substantially as follows: Total trough length 44 feet, 6 to 8 inches wide. The water flowed 22 feet through two joined troughs with a fall of 2 inches, then fell 10 inches to the second set of two troughs and returned through 22 feet, with a fall of 2 inches, and was delivered into an aquarium. The troughs were painted with asphalt and sanded on the moist asphalt. When dry, pebbles of various sizes were strewn along the bed of the troughs, thus imitating natural flow in pebbly brooks.

The troughs were suspended one set above the other near the ceiling in the aquarium grotto and the water delivered into the head of the upper from a rubber tube. Two trials were made in the sanded troughs, but without pebbles, with a flow of 2 liters per minute. The following table shows the correcting effect of such troughs.

TABLE II.—WATER FROM ELECTRIC PUMP BEFORE AND AFTER PASSING THROUGH SANDED TROUGHS WITHOUT PEBBLES.

Date.	Sample.	Water temperature.		CO_2.	N.	O.
		Entering troughs.	Leaving troughs.			
		°C.	°C.			
May 3	Well water, untreated	15.5		38.1	21.0	0.1
May 4, 12.30 p. m.	Well water, at exit of troughs	15.5	17.5	19.2	14.9	4.5
May 4, 2 p. m.	do	15.5	17.5	13.9	14.1	4.4

Since the determination of May 3 on untreated water agrees approximately with the figures obtained several days earlier, it may be assumed that the water does not vary beyond the limits shown in table I. This variation, however, is considerable and as two samples could not be determined at the same time, it is not known exactly what the condition of any treated water sample was at the time it entered the troughs. It is known approximately, however, and it is apparent that the 2-liter flow water is considerably but not completely corrected for nitrogen and that much oxygen has been added but not enough to air-saturate with oxygen. At this point the pump ceased to deliver water on account of clogging with sand. No more determinations were made until May 14. In the meantime a small hydraulic pump was connected with the well and succeeded in pumping some 4 gallons per minute. This pump, however, changed the aeration of the water considerably.

The electric pump had its pumping cylinder entirely immersed and some 30 feet below the surface of water, so that all pipes were filled with water under pressure instead of suction. There was therefore no opportunity for atmospheric air to enter the pipes. The hydraulic pump on the other hand was located on the surface of the ground and had a suction pipe some 22 feet long. Though no leak was discovered, the pump delivered gas in large bubbles, much more in quantity than ever came from the electric pump. This gas, or air, must have entered the suction area at some point and though insufficient to stop the pump, modified the air content in an interesting way, as shown by comparing the "untreated" samples in table III with table I. Oxygen has been increased, while the nitrogen has not been materially changed or has even been reduced somewhat. The explanation is found in the atmospheric air which gains access to the hydraulic pump. The water having scarcely any oxygen loses little or none in the suction pipe, but takes up considerable in the pressure pipes between the pump and the point of delivery, on account of air taken in at the suction and propelled in company with the water past the pump, where it is then under pressure. The water having an excess of nitrogen must lose considerable in the suction pipe on account of the reduction of pressure. This nitrogen which comes out of solution remains within the pipe as free bubbles and together with the atmospheric air sucked in, passes on with the water past the pump when the pressure then causes nitrogen to be forced back into solution in the water. The resultant of these two opposite processes is evidently a slight diminution in the nitrogen content. This is reasonable, since the suction below the pump is greater than the pressure above it.

It is thus seen that although a leaky suction pipe in pumping systems usually injures the water from a fish-cultural point of view, in this case it improved it somewhat, by adding oxygen and subtracting nitrogen. It did so because of the great length of suction pipe, the small head pumped against, and

the extreme faults of the water in the well with respect to both oxygen and nitrogen.

In addition to the troughs, tin pans with perforated bottoms were used to correct the water. Usually the water was passed through a series of 6, arranged one above the other, with a fall of 4 inches from one bottom to the next. The pans were rectangular, about 31 by 19.6 by 5 centimeters, and contained 345 circular holes 1 millimeter in diameter, regularly placed, punched from the inside with a steel punch. In table III the results with these pans may be compared with those from the troughs, on 2, 4, and 6 liter flow. The "untreated" samples were taken directly from the delivery pipe before appreciable contact with air. In comparing the results, or when considering in any case the amount of air or any gas dissolved in water, the temperature of the water must always be borne in mind, the colder water holding or being capable of holding more gas dissolved than warmer water.

TABLE III.—WELL WATER FROM HYDRAULIC PUMP, UNTREATED, AFTER PASSING THROUGH SANDED AND PEBBLED TROUGHS, AND AFTER PASSING THROUGH SIX PERFORATED PANS.

Sample.	Date.	Flow per minute.	Temperature of water. Entering troughs.	Temperature of water. Leaving troughs.	CO_2.	N.	O.
		Liters.	°*C.*	°*C.*			
Untreated	May 14, 3 p. m.	6	17.5		44.0	16.9	4.6
Do	May 14, 4 p. m.	6	17.0		46.4	16.8	3.7
Do	May 15, 9.30 a. m.	6	16.5		45.7	21.0	2.6
Through troughs	do	2	16.75	18.75	8.5	13.2	5.6
Do	May 15, 5 p. m.	4	16.0	18.0	12.5	13.7	5.2
Do	May 16	6	15.5	15.0	15.2	15.1	5.1
Through 6 pans	May 15, 3 p. m.	2	16.5	17.5	7.9	13.3	5.8
Do	May 16, 4 p. m.	4	16.25	17.25	11.4	14.0	5.3
Do	May 16, 12 noon	6	15.5	15.5	13.9	14.8	5.4
Untreated	May 16, 9 a. m.		15.5		45.6	23.0	1.1
Do	May 16, 1.30 p. m.		15.5		45.8	22.5	1.2

Several facts of interest appear from the trials of the pans and troughs. In the first place, neither succeeds in completely correcting the water with respect to either gas. After passing either system the water could, by further exposure, take up a little more oxygen and release more nitrogen. With the 2-liter flow, however, the correction is very nearly complete for oxygen, but it must be remembered that the hydraulic pump had already added some oxygen. The correction is less complete by both troughs and pans as the flow grows

larger. As between the two systems, the troughs and perforated pans, the difference is insignificant on the smallest flow (2 liters) and is in favor of the pans. As the flow increases in volume, the advantage of the pans becomes somewhat more appreciable, but even with the 6-liter flow the troughs are a practicable method of correcting water. Unfortunately, larger flows than this were not tested with the troughs. The following two determinations were made on a flow of 12.5 liters per minute, delivered May 3 by the electric pump and passed through pans each perforated by 345 holes of irregular size, but all of them considerably larger than 1 millimeter. The condition of the water before treating is shown by the "untreated" sample, and is substantially in agreement with that shown by table I.

Sample.	Hour.	Temperature of water.	CO_2.	N.	O.
		°C.			
Untreated	2 p. m	15.5	38.1	21.0	0.13
Through 5 pans	11 a. m.	15.5	27.2	17.4	4.0
Through 6 pans	1 p. m.	15.5	16.8	15.9	4.8

The water after passing 6 pans still has about 2 c. c. too much nitrogen and about 1 c. c. too little oxygen per liter. The correction is less complete than in any other case, on account of the larger flow and the larger holes in the pans.

From tables II and III it is seen that the pebbles contained in the troughs add considerably to the efficiency.

The practical application of these experiments may be found in their showing that aeration and deaeration sometimes require an extremely thorough or intimate exposure of water to the atmosphere to restore the dissolved air content to the normal. The water must be spread into very thin sheets, as in troughs, or if subdivided into streams, as by perforated pans, must be reunited and subdivided repeatedly. By increasing the lengths of trough or the number of pans, the correction can finally be made complete. Troughs have practically the efficiency of pans under the conditions of trials described herein. The objection to them lies in their warming of the water if the air temperature is high, their expense and cumbersomeness. One great advantage they possess is that they require little vertical space, and therefore they could be used where the fall from tap to trough is too short to permit the insertion of a sufficient number of pans, provided there is sufficient room laterally.

When pans are used, the diameter of the holes must be controlled largely by the volume of water, the amount of fall available, and especially by the sediment the water carries. The smaller the holes the better, as far as

exposure to air is concerned, but they readily clog with suspended matter. Moreover, they do not allow the delivery of so much water as larger holes, unless the pressure is increased by deepening the pan, but this takes up vertical space. Larger holes to avoid clogging may be compensated by more pans. The size and depth of pans, number and size of holes, will be a resultant of the various factors mentioned, and may be determined by the judgment of the fish culturist for each particular case, or by trial and experiment.

Since the water from the well under consideration has a temperature of 15.5° C. or 60° F., when it arises, it can not undergo warming and remain fit for trout. Could it be passed through an efficient aerating apparatus of pans, trout could probably be maintained in it even during the heated season, since the passage through pans is rapid enough to warm the water but little. Any form of aeration, however, will seriously interfere with the clearness of this water, since it contains about four parts of iron per million dissolved as some one of the salts of iron. On exposure to air most of this iron is precipitated, and causes a marked turbidity. On standing, the particles of iron oxide settle and the water becomes clear; but for constant-flow aquariums it would require filtering before use. This would warm the water, and its use therefore would involve more trouble and expense than that which the well water was intended to obviate.

Thus this well water is of peculiar interest in having two faults, the correction of which induces a third almost as serious for exhibition aquarium purposes. The excess of nitrogen or the deficiency of oxygen are either of them singly sufficient to kill all the fishes placed in the water. Both are remedied simultaneously by one process, thorough exposure of the water to air; but this process creates, by oxidation and precipitation of dissolved iron, a turbidity which ruins the water for the purposes of aquarium exhibit.

DETERMINATION OF SUITABILITY OF WATER FOR FISH CULTURE.

Entirely aside from any question of parasitism, and speaking only of dissolved substances, it must be admitted that there is at present no sure method of determining by chemical tests the suitability of water for fish culture. Much of course may be assumed in favor of unpolluted natural streams, as trout streams for trout culture. With spring water nothing may be assumed. Something may be learned from a chemical examination, but it must be adapted to the purposes of fish culture. Ordinarily, if a sample is submitted to a chemist he will make what is called a sanitary analysis, which determines whether water is fit for drinking and domestic uses—is healthful for human consumption. For fish culture this is almost useless. Water with a good sanitary showing may kill fishes in a short time, and on the other hand, in rivers fishes are not

necessarily harmed by water which any chemist would pronounce unfit from a sanitary standpoint.

There must be established what may be called a fish-cultural analysis, and the information this will give should cover, among other things, the reaction and degree of alkalinity or acidity, hardness, total solids, sulphates, nitrates and chlorides, the carbonic acid, the dissolved oxygen, nitrogen, and carbon dioxide; and an ordinary mineral analysis with special tests for any unusual metals which there is any reason to suspect. The determinations of the atmospheric gases named should be made on the perfectly fresh sample. The dissolved air is the most important, and the nitrogen as important as or more so than the oxygen. Temperature, turbidity, color, etc., are physical characters which the chemist will note. Having obtained these results, not all of them can yet be accurately interpreted. For the atmospheric gases one can form immediately a fairly definite opinion, but as for total solids and the minerals present, we know but little of the limits of safety. Therefore it is that the final test is experience itself. A long experience with fish culture and aquarium experiments in water whose contents are accurately known will ultimately lead to the establishment of definite standards which will be useful to fish culture, just as the long-continued chemical examination of service waters in the light of the results of their usage has led to standards confessedly not well defined, but which are nevertheless useful in selecting sanitary waters.

CAUSES OF DISEASE IN YOUNG SALMONOIDS

By Eugene Vincent

Fish Culturist, Aquarium of the Trocadero, Paris

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

CONTENTS.

	Page.
Diseases of the gills	909
Faulty hatching equipment and conditions	909
Measures of prevention	912
Curative measures	914
An epidemic of "staggers" in rainbow trout fry	914

CAUSES OF DISEASE IN YOUNG SALMONOIDS.

By EUGENE VINCENT,
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[Translated from the French.]

The common trout and its varieties are especially subject to disease of the gills, and other salmonoids likewise are not exempt from it. Such disease consequently presents great difficulty to fish culturists, who must find means of combating it. Another frequent trouble is the epidemic which may be called "staggers." The effective measures in both cases are those of prevention rather than attempt to cure; and the best means of prevention is perfect cleanliness of equipment, from the beginning of the hatching period throughout. To maintain the necessary cleanliness, however, is a question of style of apparatus as well as unremitting care.

DISEASES OF THE GILLS.

FAULTY HATCHING EQUIPMENT AND CONDITIONS.

As fish culturists well know, the styles of apparatus for incubating eggs of the salmon species are very numerous. In France the most common equipment is the Coste trough and its derivatives, consisting of a kind of rectangular zinc box 0.50 to 0.60 meter long, 0.25 meter wide, and 0.20 meter high, with two partitions of perforated sheet iron, the one serving to admit the water from below, the other allowing it to pass out from above. Into this box is set a glass grille of dimensions to fit.

I have heard much in praise of all varieties of apparatus, but I have heard little concerning their disadvantages and dangers. It is of these latter that I shall speak.

First of all, I consider the equipment bad which does not allow the fish culturist to see what is taking place below the grilles on which the eggs are resting or permit of cleaning without disturbing the eggs.

We are told that there are currents of water in this apparatus, which receive as much as one-half liter of water per minute. There can be no currents of water in these troughs, however, especially in those with partitions; there is, to be sure, a change of water, but there is no current which would bring about a flow throughout, and this may be easily shown by putting into the water coloring matter or thin strips of paper. And it is precisely the absence

of this current which determines and creates the dangers to which the eggs and the fry are exposed—this, first, because the quantity of water supplied to the apparatus is not sufficient; second, because all obstacles, as the partitions in the apparatus, operating to prevent a current, become a hearth of infection of all kinds, by the corners they make; third, because of the very dimensions and the shape of these troughs; and fourth, the visible proof, because there are found in these troughs and in the rearing troughs fry large enough to be able to maintain an equilibrium, yet lying on their sides, with gills compressed against the bottom of the basin and in contact with the slimy ooze of the bottom. If the fish makes a movement, it is only to fall back on the other side, so that the gills are by turn infected with noxious substances from the bottom, which can not be seen and cleaned as it ought to be.

The greatest cleanliness is always necessary in fish culture, and it must be made attainable. Let us see, without being pessimistic, what the conditions most often are.

The fish-cultural apparatus found on the market has not all been invented by fish culturists having a knowledge of this science. The manufacturer sells apparatus the advantages of which he extols with the aid of so-called fish-cultural tracts (though in reality they are not such), and the inexperienced purchaser establishes his business immediately, with confidence of success.

If he buys eyed eggs, he will not have the same difficulties as the man who collects the eggs himself. Let us take the latter for example. The eggs are placed on the grilles and the grilles in the troughs, all these things being more or less well washed, but the wooden screens can not be put in the flame so as to destroy all germs. Then there may be among the eggs excretions of fishes that may have fallen in the stripping, or there may be shells of broken eggs, all of which may drop through the grille to the bottom of the trough, to be left there during the entire period of incubation, together with any dead eggs that may have slipped between the glass bars.

If the water contains sediment, this will be deposited on the bottom of the trough and will remain there. The fish culturist has been told that all he has to do is to take out the few dead eggs and await the hatching of the others before cleaning out his apparatus. Water is not the same everywhere; all has its advantages and its disadvantages; in France the incubation takes place in water the temperature of which varies during this period from 6° to 12° C. (I do not refer to the mountain region), and often the incubation period lasts from forty-five to fifty days. It is well known that some eight days before the first hatching some eggs will burst. Their contents, escaping, spread over the eggs in long filaments which attach themselves to the grill, pass through it, go to the bottom, increase the amount of sediment, and encourage the invasion of *Saprolegnia*.

The unfertile eggs are not taken out, and the first filament of fungus may not be seen on an egg that is in a corner of the grill. But later the eggs may be covered with this delicate down, and although something might still be done for the embryos whose breathing is thus interfered with, even the flow of water has not been increased since the eye spots appeared, and so the fungus establishes itself.

The hatching time is now at hand, and may last, in water having a temperature of 10°, some ten or twelve days, and sometimes more. Until it is over there is no thought of placing the fry in a cleaner place. As the fry hatch they fall, like the shells of their eggs, to the bottom of the trough, on a soft velvet composed of the flourishing *Saprolegnia*.

And these unfortunate fry, the gills of which have never ceased being in forced contact with all the impurities and disease germs which line the bottom of the trough, are now to be disturbed in this water, the sediment in which will be visible to the operator when he shakes or moves the trough. Nor is it only the breathing apparatus which suffers, but the entire fish, for its body receives shocks and wounds, inviting the fungus, and the mouth particularly becomes infected.

The disease then has secured its hold. It is not perceived, for the operator believes that he has done all that is necessary by cleaning the fry at the close of the hatching. They may have been replaced in the same trough after giving the latter a hasty cleaning, for maybe there was no other at hand. Fry from two different troughs may have been put together without thought of the imprudence of this. The lots are then of different ages by ten to twelve days, and they are a little crowded, there being 2,000 to 2,500 in those little troughs without any increase of the flow of water—for how long? They will be fed in a month, perhaps six weeks. In the meantime there is amusement in finding a few monstrosities among them. These die from day to day and the yolk sac sheds its contents, which adhere to the bottom and form white spots which occasion no alarm. The *Saprolegnia* finds again a favorable bed for development.

The oldest and most robust of the fry, endeavoring to move about a little, reach a corner of the trough, where they crowd against each other. By their swimming movements they form in this corner a small current, or more exactly, a slight motion of the water sufficient to maintain them in equilibrium on their yolk sacs facing this small partial current. As soon as the fry ceases to feel this current it can not maintain itself on its yolk sac and falls on its side. Is it no longer so strong? No; that is not the reason—it is the motion of the water which is lacking and which does not exist in the trough in any other spot except where the fry make it themselves. The proper motion of the water is created by a device of mine which I shall describe, a siphon outlet system; but for the present I say that the eggs in incubation were not given a current sufficient to wash them, facilitate the exchange of gases, and keep them from being covered

with a thin layer of sediment. I maintain that thus the embryos also suffered, and I am sure that it is in this way the fry contract the disease of the gills.

Such is the origin of the disease which manifests itself in young fish in swollen gills, impregnated with dirt and bulging so much as to push out the operculum. The fish are seen to weaken and turn dark in color and then die, at first in small numbers, but increasing to an almost complete mortality. It may be justly assumed that those which escape are those which hatched last and have not been so long in contact with the deposit on the bottom of the trough. This terrible disease may not manifest itself among the young fish until the age of five to six weeks.

In addition to the cause I have named for the origin of this disease of the gills, it is sometimes due to placing too much food into the rearing troughs. The coagulated blood, spleen pulp, pulp of liver, etc., becoming diluted, render the water at times so tinted that it is impossible to see through it. The gills are impregnated with putrefiable matter, which soon gives rise to this terrible epidemic, especially if the water is not aerated and frequently changed. Lastly, a great number of fry in a small space, not receiving a sufficient quantity of water, acquire the disease of the gills by atrophy, as may be easily recognized by the small size and emaciation of the fish.

MEASURES OF PREVENTION.

As stated at the outset, the remedy for this disease is prevention, which involves the utmost care on the part of the attendant, with also the form of equipment which shall permit of the most perfect cleanliness. I will indicate the means I have employed and consider essential.

1. Discard all apparatus that does not allow the interior to be examined. It must be possible to see under the grilles on which the eggs are placed, and, if necessary, to clean the bottom of the trough without interfering with the incubation process.

2. Use an equipment which will permit of retaining the fry therein after the hatching is over. Discard the wooden grille frame for one of metal and replace the glass tubes with solid glass rods.

3. Have an ample supply of water in proportion to the number of eggs in the trough, and create currents to reach every part. Increase the supply of water, if possible, as soon as the eye spots appear in the egg.

4. Do not crowd the eggs on the grille. Take out the dead eggs each day. Do not refill the spaces left by the removal of dead eggs. These, taken out to prevent their bursting in the trough, will now give more space to the developing eggs. Take out any eggs containing monstrosities.

5. Give a thorough cleaning both to grilles and troughs when the eggs are ready to hatch, so that the fry may fall to the bottom of the trough without danger to their gills. A hand siphon cleaner[a] should be used for the trough.

[a] Vincent E.: Devices for use in fish hatcheries and aquaria. Proceedings Fourth International Fishery Congress, Bulletin U. S. Bureau of Fisheries, vol. XXVIII, 1908, p. 1030.

6. If the hatching equipment is not adapted for retaining the fry, transfer each day's hatch, classifying by age, to thoroughly cleaned troughs, with such number to each trough as may be held for five or six weeks. In making the transfer use a syringe of $1\frac{1}{4}$ to $1\frac{1}{2}$ liters capacity, with a tube of 0.017 meter diameter, so that the gills and yolk sac of the fry shall not be compressed. Do not keep the fry in darkness or obscurity; daylight is better for them. Eliminate monstrosities. Change the water every day, the siphon outlet[a] serving also as an auxiliary cleaner, since it creates currents in the troughs. Dispose the intake at a point to produce a longitudinal motion of water.

7. I feed the fry, to aid them in developing, beginning four days after hatching. This has been my practice for some six years, and I have found it good. I clean the troughs every day with a brush, called codfish tail, and take out any remnants of food which the siphon outlet has not carried off. When the fish are some five or six weeks old I put them in large troughs, the cleaning of which is simpler, and here I feed them with beef spleen placed in small wire baskets fixed at about mid depth of the trough, this to prevent the fish from seeking food at the bottom and so that less shall be wasted.

It is difficult in a large establishment to have really filtered water. No filter at all is better than a bad one.

Various devices of mine described elsewhere (op. cit.) have proved an aid to the realization of the necessary cleanliness in fish hatching. I have adopted also a combination trough, to be used both for the eggs during the incubation period and for the fry afterwards, thus avoiding the disturbance and injury of a transfer of the very young and delicate fish, while at the same time offering the advantages of the currents they need, besides facilities for perfect cleanliness. This trough is of cement and measures inside 1.5 meters long, 0.3 meter deep, and 0.35 meter wide. The shape is such as to aid in cleaning, having no angles, but curves only. The size is sufficient to accommodate two grilles and the siphon outlet apparatus already referred to. The interior is especially designed, after repeated experiment, to provide currents suitable for the eggs during incubation and later for the fry, to give the latter means of equilibrium and also supply them with food in a natural manner. The particles of food are always in motion in this trough. The model belongs to the firm of Leune, Rue Cardinal Lemoine, 28 bis, Paris.

It is important for the fry to be in equilibrium, and not lying with gills against the bottom, even though the troughs be clean, a condition which is attainable if there be a current, but not otherwise. As soon as there is the smallest motion giving the sensation of a current even the very young fry will respond to it. This may be tested by the simple experiment of using a syringe

[a] Vincent, op. cit.

in the water close to the fry. The little heads at once turn toward the current, the bodies righting themselves upon the yolk sac, and this equilibrium is maintained so long as the current continues. When it fails the fry fall back on their sides.

It is suitable currents that also make it possible to feed the very small fry without danger of disease. Even before the yolk sac has begun to diminish they will face the currents and make efforts to catch small particles of food passing some three or four centimeters above them. I have shown this very interesting and amusing sight in aquaria, and it is because of such experiments that I insist the fry shall be fed when four days old. At the end of ten or twelve days, in water having a temperature of about 10°, will be observed the occurrence above noted, and a few days later these fry, developed and strengthened by the food they have had, but still with their yolk sac, may be seen swimming progressively. The fry should not be kept in darkness. They must be able to see their food to get it.

CURATIVE MEASURES.

With the precautions I have enumerated the fry will not be affected with the gill disease. If, however, I should find myself confronted with it I would reduce the number of fry by half; I would place them in semiobscurity and would give them no food for several days, in order not to put into the water the slightest substance for putrefaction, and keep the gills free of any organic matter due to the food or its remains. I would have well-aerated water and take care not to leave any dead fish in the troughs. Such would be the treatment to be given—a thorough cleaning from the beginning of the disease. But I do not guarantee that I could save fry which were seriously affected.

The gills are very sensitive to the disease, and their impregnation with organic matter, be it only a temporary one, causes death. I have been a professional fisherman, and all fishermen know very well that fishes caught during the first days of rising water never live, can not live, even if they are taken with the most inoffensive of fishing devices, and this is so because their gills are filled with organic matter and sediment which rising water always carries along. Three or four days after the beginning of the rise of water the gills are slowly cleaned and the fishes live.

AN EPIDEMIC OF "STAGGERS" IN RAINBOW TROUT FRY.

The brood trout in this case weighed about four ounces and laid eggs now for the second time. The eggs were placed in filtered spring water at a temperature of 9°, 10°, and even 11°, and incubation lasted forty days. The greatest hatch took place on March 14, 1906, lasting two days. The small fry were placed in nonfiltered water, where they were kept from March 16 to April 14.

These fry were fed regularly every day, from the fourth day after hatching, with pulp of beef spleen, first crushed in a mortar, then passed through a horse-hair sieve. Somewhat later I contented myself with rubbing the spleen pulp, which was somewhat diluted, in the trough and between my hands, the fry eating this very well. On April 20, i. e., about thirty-five days after hatching, the trout, now in a pond, were eating pulp which I did not crush, but placed in a small basket suspended between two currents in the pond.

The pond was supplied with river water, of a temperature of 12½°. It was 7 meters in length, 2.5 meters in width, and 1.8 meters in depth. The flow of water was 10 liters per minute from the town supply. There were 9,000 fish. Time passed and these trout, having in only one and one-half months reached a size varying between 0.032 and 0.035 meter long, were well and healthy.

We had reached April 24 when two things happened to cause me apprehension. The allowance of food given to these trout had been gradually diminished, and on the other hand the water flowing into the basin, at the rate of 10 liters per minute, passed through a gravel filter, which did not inspire any confidence in me.

Before reaching this filter the water passed through three decantation basins, each containing about 10 cubic meters, then it rose between two walls, where it met a filter composed of medium pebbles, a layer of 0.25 meter, then a similar layer of gravel, then another layer 0.3 meter thick of finer gravel, then coarse sand 0.15 meter thick, and finally a layer of 0.15 meter of fine sand. These layers of gravel and sand were separated from each other by suitable sheets of metal.

Being able to see from the side into the interior of this filter, through glass panes 0.027 meter thick and 1 meter high, I ascertained that the filter was in reality dirty, the dirt obstructing the passage of the water through the gravel, so that the latter was kept back and rose in the basins of decantation. (It is well known that a filter made of gravel and sand does not operate well until it collects a surface layer of dirt, but on the other hand, as is not so well known, it is not necessary to wait until the surface is dirty to have the under layers cleaned.) I saw then that at hundreds of places organic matter formed with the gravel a more or less compact mass, and mold was to be found everywhere. This organic matter, this mold, consumed the oxygen contained by the water to the detriment of the welfare of the rainbow trout.

I foresaw danger in this growth of *Saprolegnia* of all kinds, and the multitudes of small animal life, some of it almost invisible to the naked eye.

The water was cut off and the upper part of the filter was partly cleaned; not thoroughly, however, as both time and space are needed for the washing

of all the gravel and all the sand, the layers of which lay flat on an area of 2.4 meters by 0.6 meter.

The filter, in short, was not sufficiently cleaned, the water was turned on again, and not sufficient note was made of the fact that it was the 8th of May and the river water at a temperature of 17°, the first result of which would be a sudden mortality among the trout. This happened, too. From May 8 to May 17 the water was maintained at this temperature, and on the morning of the last day I noticed some 30 trout dead in the pond, while the others were being carried to the grating at the outlet. Most of the fish turned over and over and made pirouettes, then jumped into the mass of water as if to cross it in one movement, but they fell exhausted and dropped to the bottom. About 11 o'clock in the morning 300 trout were dead.

The fish had "the staggers." In two days they grew somewhat dark, then they began to weaken, swam with difficulty, and could no more maintain a horizontal position; their behavior was abnormal, and they finally died. All of the trout did not show the weakening, but fell to the bottom of the pond and succumbed after opening their gills convulsively two or three times.

I gathered the dead trout with a net and counted 1,200 of them. That evening there were more on the bottom of the pond, and by the evening of the next day the mortality was almost complete. The remainder living was an insignificant number. I believe that 160 were placed in spring water, and out of these 160 only about 100 were saved.

This mortality had been caused by the imperfect action of the gravel filter and by its dirtiness, by the fermentation of the organic matter which the filter had retained when from April 24 the temperature of the water, 12°, rose to 17° about May 10. The cleaning of the upper layers of fine sand of the filter gave free passage to the *Saprolegnia*, the mycelium of which abounded in the lower parts or layers of gravel, and all this infection invaded the basin, with the effect of all as just described.

In order to remedy this at least partially, if there is no spring water at one's disposition, it is better not to use any filter than to use such as this. The great quantity of water necessary in a fish-culture establishment makes it difficult to obtain a perfect filter. It might be well to use water from a river, easily aerated if the pond is lower than the river.

The best means of doing without a filter would be to keep a small fry trough very clean, so as to be susceptible only to disease or an infection coming from without, which is much at best. In order to attain this practical result, a siphon-outlet system, of a kind such as I have devised (op. cit.), should be installed.

RADICAL PREVENTION OF COSTIA NECATRIX IN SALMONOID FRY

By Johann Franke

Director of the Fish-Culture Establishment at Studenec and Secretary of the Fishery Committee for the District of Krain

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

CONTENTS.

	Page.
Characteristics of the disease	919
Accidental development of the preventive method	920
Experience of the season of 1906	922
Precautions applied in 1907	924
The season of 1908	925
Experiments in the hatching house	925
Experiments in the pond	927
Summary and conclusion	928

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[Translated from the German.]

CHARACTERISTICS OF THE DISEASE.

I insist upon the limitation to "salmonoid fry," because I have not directly observed *Costia*, nor have I seen the characteristic exterior appearances of costiasis, on any adult fish with one exception. I saw four years ago in June, in the Stara Voda, in a broad place in the stream where the current was very slow, a pike some 23 centimeters in length with a whitish covering on the skin resembling a veil, very like figures 12 and 13 in Dr. Bruno Hofer's "Fischkrankheiten," in which work appears a full description of this disease.[a]

The place where my observations were made was the fish-culture establishment at Laibach, Austria.

The appearance of *Costia* was noticed among the fry some five to ten days after they had begun to feed, i. e., after the resorption of the sac—never before this period—and equally whether the fry began to feed early or late, among the early feeding *Salvelinus fontinalis* and alike the late *Salmo irideus*. About the middle of June, sometimes ten days earlier, all trace of *Costia* disappeared as mysteriously as it had come. I have no reliable criterion as to whether the fish became immune against costiasis in June or whether *Costia* in the form of a flagellate is seasonal, but I suppose the latter to be the case, since the signs of disease disappear at the same time among the younger and older fry.

No difference could be found in the susceptibility of the young fishes; the fry of the three species regularly cultivated—*Salvelinus fontinalis*, *Salmo fario*, and *Salmo irideus*, obtained from brood fishes of the establishment (among which may be included the 100 kilograms of *Salvelinus fontinalis* and *Salmo*

[a] Hofer, B.: Handbuch der Fischkrankheiten, p. 115–121. Munich, 1904.

fario from the excellent stream of Stara Voda)—were attacked along with the embryonated eggs obtained from elsewhere.[a] The fry that were fed nothing but live crustaceans and larvæ of mosquitoes, their natural food, were infected as much as those which, on account of temporary lack of natural food, were fed partly with substitutes, such as pig liver or beef and veal spleen.

The infection must, consequently, be of the locality. The place, the water and its near surroundings, must be infected, the shores harboring *Costia* in the shape of cysts on the dry land, whence they are scattered everywhere by the wind.

Costia had already established itself at Studenec before my arrival in 1891. Costiasis thus did not begin during my direction, but it spread so rapidly and at last in such manner that none of the springs were safe from it. It was first recognized in 1904 by Dr. Ivan Robida, head of the hospital for the insane in Studenec, who was fond of the sport of fishing and who in his close relations with myself studied questions which interested me. By means of his microscope (my own not powerful enough) and Dr. Hofer's book, the identity of the disease germ was fixed in 1905.

We conclude, further, that we have found the cause of the abnormal mortality of fry in previous years, there appearing the same phenomena and symptoms and course of the disease from the very beginning that had characterized those great losses for which no cause was known from 1896 until this time. I had sufficient occasion and opportunity to observe all the phenomena and symptoms minutely, and likewise to remember them, for a large part of the feeding fry were placed for one to three months in larger hatching boxes, then in floating troughs, and in September and October in large ponds in which to pass the winter, while I spent each year 180 half days and 40 to 60 entire days in this establishment.

ACCIDENTAL DEVELOPMENT OF THE PREVENTIVE METHOD.

The radical means of preventing *Costia* was not "discovered," nor even "found," for it was not sought. It developed in the following manner:

In the one-story house occupied by Doctor Robida and other physicians of the insane asylum there is a tank under the roof with capacity of about 1,800 liters, into which was pumped water for household purposes from a spring situated in the cellar of a house about 80 meters distant, if sufficient water was coming to the ponds for the working of the pump. The spring in the cellar and the tank are well covered and the pumped water, coming in contact with the fresh air from without only by chance rifts in the cover, can not be much

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[a] *Salmo fario* from Ilidze, Bosnia, 1902; *Salmo dentex* (Isonzo trout) from Idria, 1903–1907, inclusive.

contaminated by dust, etc. Doctor Robida took advantage of the vicinity of the tank to supply with water therefrom two small aquaria in his room (1905). From the main pipe, made of lead, the water passed into the aquaria through slender rubber tubes (3 millimeters in diameter at the outlet) with brass end pieces (about 1 millimeter at the opening), under pressure of about half an atmosphere. One of the aquaria consisted entirely of glass and had a bottom area of 35 by 25 and a height of 22 centimeters, while the other was somewhat larger and had a lead bottom and frame, with walls of glass. In the bottom of each was a layer of 5 to 6 centimeters of fine, white, well washed, calcareous sand, and a few shoots of water cress were planted in it. The water, falling in a slender jet, boiled up actively and sent out small bubbles in every direction, so that even in the corners they could be seen dancing in the water. In the first aquarium were placed more than 300 young *Salvelinus fontinalis* old enough to feed, while in the larger one were placed *Salmo fario* and *irideus*, also a few *fontinalis*, in all some 500 fry. More than any other fry these were fed with crustaceans exclusively, which were greedily devoured, especially by the American species, which fed until the body swelled quite out of shape and looked as if it would burst. The excrements were removed daily by means of a small suction tube, while once each week the aquarium was thoroughly cleaned, the sand washed, etc., the fishes being placed in other quarters during this proceeding. *Costia* had in the meanwhile appeared in the hatchery as in the preceding years, but there was no trace of the disease in the aquaria.

Ten diseased *Salvelinus fontinalis* were now put into the smaller aquarium. The infection had not as yet shown its full effect on them and *Costia* had established itself microscopically on other fishes looking like these. The diseased fishes differed from the fat, healthy ones, not only by the thinness of body but also by the coloring, which was more or less of a dark blackish blue hue, with a faint, almost invisible shading as compared to the light-colored and white markings of the healthy individuals, and the difference was apparent to the casual observer. The diseased fishes continued to live, seeking the bottom in the quietest places and rarely moving about, and looked at the last like a thin blackish thread with a thick knot. All died within 6 to 9 days after the fishes of the same lot and of the same appearance left in the hatchery. Expectation as to the results of this experiment was naturally great, but no effect was produced on the fishes in the aquarium.

A second experiment in the second aquarium gave the same result, and several more were made in each aquarium. Doctor Robida attempted to convey the infection by other means, i. e., by the infiltration of infected water and by the direct introduction of living *Costia*, but with no result. He changed the food freely, giving the fishes, when they had grown larger, grated meat from

his own table, even chopped liver, thinking that in water so well aerated even such food could do them no harm.[a]

The abundant aeration of the water proved to be a radical prevention against *Costia*, all the fish remaining alive and healthy, not one being lost. When the action of the pump grew defective on account of scarcity of water, Doctor Robida used a small motor operated by alcohol for the purpose of obtaining a current in the aquaria. But the disadvantage increased and I put the fishes, which were from 3 to 4 centimeters long, into a rearing trough (8 meters long, 0.55 meter wide, and 20 centimeters deep), merely giving them three more salt baths, since this was the end of the critical period, in order to be safe from the danger of *Costia*.

I have never seen the white veil-like covering spreading over the skin, as shown in figures 12 and 13 in Doctor Hofer's book, except on the pike already mentioned; never on the small fry. So long as I fought *Costia* with potassium permanganate and not with cooking salt, as did Doctor Hofer, the fishes which had withstood *Costia* had white fungus spots near the gill openings, and these spots, in spite of the treatment with potassium permanganate, were in some cases fatal. Since I have begun to use common salt, I have not noticed this last phenomenon. I suppose that the fishes attacked by *Costia* are too small and consequently too weak to endure this condition until the white spots show on the skin, and die before this stage.

EXPERIENCE OF THE SEASON OF 1906.

It was impossible to arrange an aeration of the hatchery troughs by means of water under pressure, on account of lack of fall in the supply. The only fall periodically in operation was occupied by the already mentioned pump and not available for hatchery purposes by reason of its location. Thus I could not put into practice the new experience with aeration.

Since *Costia* was again to be expected in the hatchery, however, I arranged in a pond, which had not been used for fishes for four years and the water flow of which was used only to supply two rearing troughs, a place in the open for the hatching boxes. This small pond was repeatedly dry when the water was low in the springs. The bottom was cleaned of all vegetation, raked and washed out, highly saturated with potassium permanganate, and after this washed out with salt. All the small fry able to feed and destined for rearing in the establishment were brought to this pond. The water, as may be easily understood, never grows muddy, has a constant temperature of 9.8° C., and produces many green algæ, which are very cumbersome when the currents of the water become slow with low water in the springs.

[a] In my opinion such food can not be given long, never exclusively, and of the latter sort not even to large fish.

These measures of precaution and a careful maintenance of cleanliness in the hatching boxes, etc., as well as the sole use of live natural food, brought about only the result that in the two boxes first installed the fry did not develop the *Costia* until four or five days later than in the hatching house, and that the infection did not spring up immediately in a violent form, but crept in upon them slowly and insidiously. It may be concluded thence that after the cleaning and thorough disinfection of the pond, etc., the water was free from *Costia*, but was reinfected by the nonsaturated ground of the banks, from cysts which must have been carried into the water by the wind. But whence come these cysts? The following explanation readily presents itself:

The dirt from the rearing troughs (during the first years of my direction there were eight of them at three different places, for the most part occupied by two separate lots of fish), the excrements, debris of food, and ooze from the algæ and the grounds were washed down into the pond water; there formed in the wintering ponds during eight to nine months at the places where the water did not course so freely a thick layer of fat, black, ill-smelling ground ooze, and the ponds could not be cleaned except by flushing them out, scraping, sweeping, and washing out the ground; all this carried off into the principal pond. The latter can be emptied only down to about five-sixths of its contents, and all the springs of the local systems flow into it, through it, and off by means of one lock. From the principal spring, which is easily accessible to the village of Studenec (three or four butchers, the cattle, etc.), much organic matter comes into the pond; it continually receives manure from this source, and incidentally from the well-frequented road during rainfall. Thus a rich bottom fauna and very abundant vegetation develop. The latter must be taken out partially several times a year and thoroughly once annually. Much ooze is naturally taken out with the *Chara fragilis*, and everything taken out of the pond is piled on the banks in heaps, where it remains sometimes for two entire years. As long as the springs were full and there was a corresponding flow of water, a total of 600 to 800 second-liters in the maximum and never less than 200 second-liters up to 1896, no bad effect was noticed on the fishes from the pollution of the ground and its oxidation. And, frankly speaking, I knew nothing, as so many others, about the importance in fish rearing of ground culture and ground sanitation. When the scarcity of water and lack of currents began to be felt and had grown quite noticeable in 1904, and the well-known effects of such conditions, among others the presence of *Costia*, appeared in the fish-cultural work, I was forced to look for explanation and remedies.

Conditions for the existence of *Costia* were rendered more and more naturally favorable by the decrease of water supply in the summer of 1905, the winter following, and later down to a very few liters, and by the fish-cultural operations; and the persistence of the infection was insured by the maintenance of

old and the establishment of new piles on the bank whence *Costia* cysts would be derived. I can not find any other explanation for the infection of the pond.

Cooking salt was again our resort; by this means I carried through the critical period one-fourth of the fishes in the worst cases and three-fourths of them in the less severe.

PRECAUTIONS APPLIED IN 1907.

The same pond was again thoroughly cleaned and disinfected, then a part was partitioned off in a shallower portion by means of a wall of clay. The water for the fry flowed through a tube of rubber and lead through the dams into the distributing trough and thence through lead siphons into the hatching boxes. The covers for these were fitted better and more closely than in 1906, and supplied with glass openings in order to give the fishes both light and sun without having to take off the covers; the distributing trough was likewise kept covered as much as possible and the cover was lifted only for the cleaning of the boxes. The flow of water was increased by five, six, and eight times the ordinary amount for the cleaning of the boxes, by which means the sediment was whirled up, flooded through the closing screen, or deposited on the latter to be swept off by means of a soft brush; the whirling up and flowing off of the sediment was aided also by means of a feather.

At the end of March, some ten days later, no trace of *Costia* was found in two boxes of *Salvelinus fontinalis*; but only fourteen days later, on April 4, I saw two fishes the color of which was not quite satisfactory. On April 5, two fishes were dead and four or five had changed color. The naked eye and the microscope both testified to the unwelcome truth—it was *Costia* again. March was very dry and very windy during the latter days. I gave the fishes a salt bath of some fifteen minutes duration on April 5 and 8. Then there was no trace of the disease until the 18th, when I gave another salt bath. It again appeared necessary to give the bath on the 20th, 24th, and 28th of April, on the 1st, 3d, 19th, 24th, and 28th of May, for twenty-five minutes, and, lastly, on June 3 for thirty minutes, when the fishes were transferred to the rearing trough.

The covering of the water was not entirely useless, the infection in the two first boxes having had two long intervals, the first ten and the second twelve days. The three lots nearest to the outflow needed the salt bath most frequently, i. e., every other day without intermittence; these were *Salmo irideus* of May 3 to June 13. The explanation of this fact is the following: The cover of the trough had to be taken off every morning and every evening during cleaning time, and this admitted the dust and the cysts, caught up by the wind, which were brought by the current to the outflow in greater quantities than at the place where the water flowed in.

I carried through the critical stage about 4,000 *Salvelinus fontinalis*, which were kept in three boxes, the last 1,400 being taken by myself on August 17

to the Wocheiner Lake, a journey from 5.30 a. m. until 1 p. m., without incurring any loss; the fish were from 5 to 7 centimeters in length.

I could not detect that the salt water did any harm to the fishes. The water was of course aerated incessantly by taking it up in a 2-liter vessel and pouring it back from a height of 50 to 70 centimeters. Only the *Salmo fario* remained at the bottom during this proceeding; the *irideus* and the *fontinalis* had to be kept out of the way with a gauze hand net.

Doctor Robida did not take any part in my experiments in 1906 and 1907, and left Studenec last year.

THE SEASON OF 1908.

The drying up of the springs, which was no longer doubtful, in addition to the spreading of the *Costia*, decided those in authority to abandon the locality near Studenec. But my desire and hope that my fish-cultural difficulties would end with the year 1907 were not fulfilled, as the spawning season of the salmonoids came round before measures for abandoning the locality could be taken.

Since I could command my time, I wished to make use of my knowledge of the effect which the introduction of atmospheric air had upon *Costia*. I sought, first, suitable cylinders, similar to those of the Hydrobion; air was pumped into these and was to rise gradually from the bottom of the fish troughs in small bubbles to the surface. Two attempts to obtain the clay cylinders met with failure.

Salt baths are good, and capable of saving the fry from entire or enormous losses; but they can not be lastingly effective if the water is continually infected anew, and they must, consequently, be repeated; and even while applying them every forty-eight hours I had to register losses which amounted in time in the most favorable cases to one-fourth of the fishes placed in the basin. They also take much time, for a man can accomplish at the same time the necessary aeration of the water in but two or three hatching boxes at the most; ten boxes would thus demand four to five hours.

EXPERIMENTS IN THE HATCHING HOUSE.

The distributing trough in the hatching house stands some 48 centimeters above the ground and is 22 centimeters deep. I placed the hatching box on the floor and obtained thus a fall of 33 centimeters. A siphon having 8 millimeters interior diameter gives, by exact measurements, 4.2 liters per minute; the capacity of one box is 2,514 liters, and the water is changed therein in 5.98 (6) minutes with one siphon and in three minutes with two. I placed above the hatching box a basin 75 centimeters interior depth, containing 250 liters of water. The water flowed therefrom into the hatching box through a flexible rubber tube 1 centimeter interior diameter and with a conical nozzle of zinc with an opening of

2.5 to 3.5 centimeters. The pressure of the water in the basin varied between 130 centimeters at the maximum and 55 centimeters at the minimum. According to the opening of the zinc nozzle the upper basin was emptied in fifty to thirty-five minutes. The falling jet of water was so placed that the water in the hatching box began to rotate. The upper basin was filled two or three times daily for one hatching box.

I placed *Trutta lacustris* in the hatching box, fry obtained from very beautiful, large, eyed eggs, of which I received 5,000 from Schliersee in Upper Austria. The eggs were placed, on January 31, in two California hatching boxes (without the inner set of brass wire trays) between flat roof tiles. The first hatched fishes appeared on March 23 in the receiving boxes placed below. The two boxes in which the eggs had been placed were opened and 81 eggs were found thickly covered with ooze and fungus. Since the fry were very unevenly hatched, they were placed immediately in two clean and thoroughly darkened boxes, being transferred first to one and then to a second under the falling water and fed with live food. On April 28, when the fry hatched latest had exchanged their light coloring for a darker, and fed as greedily as the older fishes, they were sent to the Wocheiner Lake, which they reached "in faultless condition," according to the report of the recipient.[a]

The temperature of the water used in February was 4° to 5°, in March 5° to 8°, but rose later to 10°, then to 13° C. Until April 12 there were no losses; after this there were three in all, one fish being choked by a crumb. No *Costia* was apparent. On March 30, some seven days later, the second siphon was set flowing for the first lot, consequently 8.4 liters of water were received per minute; the same was done for the second lot.

As a control lot, on March 28, 30 fish had been placed in a small box (containing 1,362 liters of water, flow of 4.2 liters per minute) arranged as heretofore, i.e., on a level with the distributing trough without waterfall or increased pressure. On the 3d of April I noticed two weak fishes, one of which was found dead on the 4th, and I found *Costia* by a microscopic investigation of another fish showing signs of disease. After giving a salt bath to the remaining fishes I left them to their fate in a spring of the pond.

I saw *Costia* renewed between afternoon and the next morning in a control lot of *fontinalis* during the last third of April in spite of salt baths. For security and my own satisfaction I gave a salt bath of 1.5 per cent of 35 minutes' duration to a lot of *Trutta lacustris* in the morning of April 25 and 27 before shipping them away.

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[a] The transportation in two casks of 128 to 132 liters lasted 1½ to 2 hours by wagon, 2 hours and 22 minutes by rail plus 47 minutes and 13 minutes standing, a total of 6 hours and 35 minutes. The water was cooled in the hatchery and when placed in the railway carriage was of from 10° to 7.5° C. The day was warm and sunny. The dimensions of all the boxes were 52 by 33 by 22 centimeters. The depth of the water was 15 centimeters.

EXPERIMENTS IN THE POND.

It was not possible to arrange a waterfall there. I placed two barrels containing 200 liters, so that the water flowed, as in the hatchery house, through longer or shorter rubber tubes, according to necessity, and in slender jets into all the hatchery boxes. The board covering of the cut-off part of the pond had been removed in the preceding autumn and had not been renewed. The maximum of the pressure was 118 centimeters in both barrels, the minimum 33 centimeters. The filling of each of the barrels took place at least twice daily, later even as often as five times. During the first week the water had to be led up from the pond over a small scaffolding, as the spring was still too weak, but after some rainfall the water could be pumped straight from the pond.

On March 27 two boxes with *S. fontinalis* were set up. On April 4 *Costia* was noticed among them in spite of the jet of water from the barrels. The daily aeration of the water for 1½ hours to 2 hours was of too short duration and too little effective with the pressure obtaining. The outflow pipe of the barrel and the small opening of the nozzle were frequently clogged by things carried in by the wind and taken up by the pump.

There were seven boxes in all and in each of these the fry received a salt bath of 2 per cent for thirty minutes every other day. To all appearances the aeration and the streaming of the water from the barrels did not remain without effect. The boxes could be thoroughly cleaned during the whirling of the water, and it could not be denied that the fishes grew more lively in the currents, darting through the whirls after the food without paying any attention to the fact that the jet of water pressed them downward; and, the most important of all, losses were not so frequent as heretofore and amounted (by estimate) to not over one-quarter in the maximum, and in a lot of *S. irideus* it was very small, in fact inconsiderable.

This lot came from large, beautifully colored parents. I had, however, done a foolish thing with the eggs. Since it is very difficult and takes a great deal of time to place the eggs regularly on the tiles so that they will not touch each other, I had ordered flat, round depressions made in regular rows in two zinc sheets in order to facilitate the work. The placing of the eggs was effected beautifully, but think of my horror to see, after opening the breeding boxes, instead of the hoped-for 1,900 or 2,000 fry, only 378, although these were almost all large and fine. Ooze had settled in the depressions with the eggs and filled the spaces between them.

On April 14 these fry were put in the pond and were cared for more than the others in regard to food and aeration. Up to May 1 the losses amounted to 25 fishes; up to June 3 there were only three more. After June 11 there remained only three boxes to be taken care of, and the above mentioned *irideus* were

treated to more frequent aeration, from eight to ten times daily. Beginning with June 24 I ventured to omit the salt baths, and since no losses resulted I decided to omit the baths entirely and confine myself solely to aeration; rightly, too, as I saw afterwards. On June 16 the fish were all sent away in a cask, fresh and healthy. The cask contained 63 liters of water without ice. Duration of transportation, 1 hour and 30 minutes by wagon, 1 hour and 30 minutes by rail, 2 hours and 30 minutes by wagon, in all 5½ hours. At the pond 3 fish were found dead, wounded by lumps of ice which were put into the water in the railway car without any ice bag.

SUMMARY AND CONCLUSION.

I come to the following conclusion from the above-mentioned experiments: A means for the radical prevention of *Costia necatrix* in salmonoids under culture is to be found in the abundant and constant introduction of atmospheric air into the living water; in other words, abundant and constant aeration.

Can deeply infected fishes be cured and saved? I doubt it. I have never seen that surface wounds and abrasions of the skin healed; fungus invariably assailed the injured places and extended over the neighboring areas more and more until there ensued weakness, difficulty of moving, and lastly death, while deep wounds, bites, thrusts, and cuts were often found healed and leaving scars.

Costia lives and increases on the skin and on the gills and destroys their tissue. Cure is always possible in the beginning of the infection, and the following phenomenon may be pointed out: All the fishes presenting a suspicious appearance—i. e., showing signs of weakness and discoloration and refusing food—were taken up by me with a gauze hand net and washed out in the water flowing from the hatching troughs. There was always water around the hatching boxes 3, 5, to 10 centimeters deep, according to the height of water in the pond. Here all around the breeding troughs and in the narrow waterflow to the pond there came again and again small fishes, mostly *S. fontinalis* of the same size as in the boxes, about 50 in June, and these seemed to be quite healthy, catching greedily at the crustaceans falling from the boxes. As it was impossible for them to come through out of the boxes, either these were cured fishes or I have taken uninfected fishes out of the boxes.

It need not be mentioned that *Costia* spreads more rapidly when the fry are crowded and that the rise of temperature above 10° C. accelerates the progress of the infection and its communication.

TREATMENT OF FUNGUS ON FISHES IN CAPTIVITY

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TREATMENT OF FUNGUS ON FISHES IN CAPTIVITY.

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A large specimen of brook trout (*Salvelinus fontinalis*), which was caught with a hook in Sunapee Lake, New Hampshire, was received at the New York Aquarium in the spring of 1896. The trout had a wound on the head. A few days after being placed in an exhibition tank fungus appeared on the wound. The writer treated the disease by applying salt water from the bay, which is pumped into the aquarium. A hose was used, the end being kept near the head of the trout, so that the stream of salt water reached the wound. This operation was repeated until the fungus disappeared. The wound healed and the fungus did not again appear.

The use of salt water has been continued in the treatment of the fishes. If the water in the bay is not of sufficient saltness to cure fungus, I use enough rock salt to increase the specific gravity to near 1.028, which is about the specific gravity of ocean water. Most of our fresh-water fishes will endure this treatment for a time, but it is necessary to keep watch on some species, or they may die if the salt water is used too long.

The usual method employed is to draw the fresh water out of the tank to about 10 or 12 inches in depth, or perhaps less if the fishes are not frightened, stopping the inflow of fresh water at the time. The tank is then filled with salt water. By this method the fishes rarely, if ever, appear to suffer any inconvenience, as the change from fresh to salt water is gradual. When necessary to use rock salt, this is put into the tank before running in the salt water, as the current aids in dissolving it. The water need not be kept in circulation in the large exhibition tanks during the treatment unless one has plenty of salt water to waste; the stream may be cut off for a time, but it is necessary to keep watch on the fishes; as soon as any uneasiness is shown the fresh water should be turned on. It is often necessary to repeat this treatment each day in order to effect a cure.

In the year 1907 and the winter and early spring of 1908 the Croton water was in such condition that fungus was more prevalent, gave more trouble, was

more difficult to cure, and was fatal in more cases than at any time in the history of the aquarium. Salt-water treatment did not cure as before, and the use of hydrogen dioxide was commenced. If a fish has only two or three diseased spots, it may be taken out of the tank with a net and the dioxide applied with a sponge. When the fungus is distributed over a considerable portion of the body, the fish is immersed in a solution of one part hydrogen dioxide to three or four parts of water. The length of time fishes will endure the treatment varies much with different species. It is necessary to watch them closely or some will be injured or killed.

Fungus has been killed on hundreds of fishes, of many species, in the New York Aquarium, by the application of hydrogen dioxide, and the fishes have been kept on exhibition for weeks, when they would have died in a few days without the treatment. Treatment for fungus should commence as soon as it appears; if not, it soon eats into the body and weakens the fish, making the cure more doubtful.

After treatment it is most necessary to take precautions against a recurrence of the fungus. In my experience, in many cases it is not difficult to kill fungus on fishes, but when this is done the affected place is left a sore, and the fish is more or less weakened by the disease and treatment. Therefore, when put back into the tank in the same water from which the disease was contracted, the fungus soon appears on the places formerly affected. Each recurrence reduces the strength of the fish and in many cases death occurs in time. I believe that if after treatment the fish could be put into new water practically free from fungus the sores would heal and the disease would not reappear. A human being contracts pneumonia and recovers, but is not exempt from contracting the disease again; in fact, under the same conditions, he may be more liable to a second attack.

In March, 1908, when fungus disease was so prevalent in the aquarium, there were two tanks of fishes, one of rock bass (*Ambloplites rupestris*) and the other spotted or channel catfish (*Ictalurus punctatus*), both of which species were attacked. Salt water was used, but without any beneficial effect. Hydrogen dioxide solution was used until the fishes were entirely cured. At the present time, September 10, 1908, every specimen of both species is in fine condition.

Fishes in house aquariums can be treated for fungus by taking the diseased specimen out of the aquarium and immersing it in prepared salt water, or in a solution of hydrogen dioxide. A small quantity of either preparation will be sufficient. If kept for some time, the dioxide will lose strength and become less effective.

METHODS OF COMBATING FUNGUS DISEASE ON FISHES IN CAPTIVITY

By Charles F. Holder

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

METHODS OF COMBATING FUNGUS DISEASE ON FISHES IN CAPTIVITY.

By CHARLES F. HOLDER.

The few suggestions made in this connection are the result of observations made in several tank aquariums and a series of open-reef aquariums on the Florida coast for the study of corals and fishes.

Fishes in confinement are subject to fungus disease in a ratio as the conditions under which they are kept differ from those of their normal habitat. Such differences vary largely with the intelligence or ignorance of the keepers, or their carelessness. Fishes are handled improperly, have been injured previously or in their capture; they are overfed and food collects in the tanks; aeration is incomplete; there is an overabundance of algæ; or the cement of the tank may be poisonous. All these factors are causes of disease, as I observed in the New York Aquarium in 1873, in the Santa Catalina Zoological Station in 1903–1908, and in Florida where aquariums were built out into the reef.

It has been my experience, then, that if preventive measures are sufficient few fish are diseased or lost, and the point of my suggestions relating to fungus affecting a species of fish under cultivation is that the Chinese method of materia medica should be adopted—namely, not to cure but to keep well. A set of rules bearing on the prevention of disease should be observed by every aquarium attendant. Such rules are as follows:

I. Never take out fish with the bare hands. Lift them carefully with a large fine-mesh net. Under no circumstances touch them, as handling often produces fungus.

II. Give the fish proper and natural aeration. The surf or near-shore fishes require more or direct aeration; deep water forms require less.

III. Never allow food to collect in the tank. Have every tank supplied with an abundance of natural scavengers—crabs of various kinds, barnacles (sea water). In fact, it should be the most important qualification of an attendant to know how to equip a tank to give the fish natural surroundings. The habits of the fish should be known, its usual food given it, and the balance should be preserved in the tanks, each being supplied, so far as possible, with the conditions found in natural life.

The following are some experiments successfully tried at the Avalon Zoological Station.

1. Fungus growth developed on sculpins. Investigation showed that there were 50 per cent too many in the tank. The fish, a near-shore, rocky-bottom species, needed maximum aeration; this was increased and in a few weeks the fishes were in the best of condition.

2. Male sheepshead constantly died because attacked with a virulent fungus; swam at the surface with the head out of water; showed bruises over body, and lacerated fins. Attendant diagnosed the case as "fish sickness." The habits of the fish were carefully studied, a man watching them even at night. This watcher reported that as soon as the lights went out the largest males attacked the other males furiously and repeatedly bit and lacerated them. The next day two sheepshead tanks were arranged, each with one male to ten or twelve females. In these there was no more difficulty with fungus growth.

3. Surf-fish were attacked with malignant fungus growth. They were in a tank with air coming up through the bottom, thus receiving the minimum amount of aeration. The surf-fish in California lives near the surf and requires the rush of well aerated water. Surface aeration of a violent kind was provided and the fishes recovered at once.

4. A mysterious illness attacked rock bass. Examination of the tank showed poor sanitary conditions. The fish were invariably overfed, the débris collected at the bottom, and the underside of the rocks was covered with "white." Feeding was stopped for several days, a larger per cent of salt introduced, and scavengers—hermit crabs, mollusks of various kinds—were put into the tank. In two weeks the tanks were completely sanitary.

5. Fish in a standing tank were troubled with fungus growth. It was suspected that the evaporation (near sunlight) was too rapid, and fresh water was added, a quart at a time. The fishes recovered, apparently showing the trouble to be too much salt.

Briefly, I would advocate, instead of elaborate and expensive treatment of fishes, prevention; in other words, a study of the habits of fishes, so that each one kept in confinement may be given the conditions and environment it requires. If this is done, at least in my experience it has so proved, fungus disease need not be dreaded, as it will not appear.

As to treatment for fungus, however, if the fish is a common one and easily replaced, as trout, remove and destroy it at once and waste no time on it. If the fish is rare and treatment is necessary, remove it to a new *tried* tank and double or quadruple the aeration from overhead or direct fall. See that the tank has scavengers (crabs) sufficient to keep it perfectly pure and clean. If fungus has developed, take the fish out, using gloves, and wipe the spots with a sponge dipped in a strong solution of salt and water. Stop feeding for a few days; then give the fish its natural food, if this can be determined.

A NEW METHOD OF COMBATING FUNGUS ON FISHES IN CAPTIVITY

By Paul Zirzow

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

A NEW METHOD OF COMBATING FUNGUS ON FISHES IN CAPTIVITY.

By PAUL ZIRZOW.

[Translated from the German.]

Several methods have already been proposed and used for combating parasites attacking fishes and for the treatment of diseased fishes. These methods consist in the application of baths of dilute watery solutions of substances which act as death-dealing agents on the micro-organisms. Greatly diluted solutions of salicyl and ammonia have been used for such baths. The use of ammonia (1 : 1000) for this purpose, proposed by Doctor Roth, of Zürich, proved more effective than salicyl, according to experiments made at the biological station of Munich, as this agent entirely kills off parasitic worms.

The treatment of fishes with baths of this kind has, however, the disadvantage that the fishes themselves suffer from the effects, so that the treatment can be given only with the greatest precaution and during a short period. In order to obtain a complete recovery, repeated baths have been recommended. The treatment of fishes, especially those attacked by fungus diseases, is necessarily very tedious, since the destruction of fungus growth can not be attained so quickly as the extermination of parasitic worms.

This disadvantage in the length of time required for effectual treatment with baths, as well as the injurious effect upon the diseased fish, may be overcome by a method which has been used hitherto only in the transportation of live fish. The feasibility of this method has been shown by the results of several experiments.

The new method of combating fungus diseases consists in keeping the diseased fishes in water regenerated by ozone until the disease has disappeared. The adequacy of such treatment was demonstrated by an experiment which took place in Galatz in October, 1906, during test of a method of keeping fish alive by means of water regenerated with ozone.

This experiment, in which tench, carp, and shad were used, showed that injured fishes which had fungus filaments and growths on their wounds when

they were placed in the experiment tanks of a special car and treated with ozone were gradually recovering as the experiment progressed, and that at the end of the 118 hours of the experiment the fungus growths had disappeared.

The tench that had been used in the experiment were placed in the Danube in a floating inclosure and after some four weeks were again, with some carp, loaded into the special car to be carried back to Berlin. Some of the tench again showed signs of fungus. The total quantity of fish used for this experiment was 725 kilograms of tench, 1,500 kilograms of carp, and a few kilograms of pike. The saturation of the water was about 50 per cent, there being 4,500 kilograms of water. The car reached Berlin after a journey of about seventy hours, and it was found that on this occasion likewise, in spite of the abnormally high saturation of the water, the growth had again disappeared on the fishes and the wounds were healing. The fishes were in good condition, and were kept in receptacles a long time after being unloaded.

Experience gleaned during these experiments indicates that in the use of ozone for the regeneration of water it is possible to combat the invasion of fungus growth and to cure the fishes attacked by this disease.

The method may be applied by keeping the water in which the diseased fishes have to be held during their disease in constant rotation and by saturating it during its motion with ozone generated by dark electric discharges.

EXPERIENCE IN ABATING DISEASE AMONG BROOK TROUT

By Albert Rosenberg

Proprietor Spring Brook Trout Hatchery, Kalamazoo, Mich.

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

EXPERIENCE IN ABATING DISEASE AMONG BROOK TROUT.

By ALBERT ROSENBERG,

Proprietor Spring Brook Trout Hatchery, Kalamazoo, Mich.

Mr. PRESIDENT: I shall ask your kind indulgence at the beginning of this paper to give you a brief history of my own fish-cultural operations, as this is essential to the subject.

I established the Spring Brook Trout Hatchery in 1895 without having had any practical experience. The site on which operations were commenced was a basin of about 4¼ acres surrounded by high hills. The water supply originates at the north end of the basin at the foot of the hills, where is a number of what are called in this part of the country (Michigan) spring holes. The land was covered with tamarack, elm, ash, etc. These were all cut off and a dam 209 feet long was built across the site, flooding about three-fourths of an acre. Eight ponds were excavated by hand labor, as the soil was muck, and ditches were dug to carry the water from springs that were uncovered. I took about 20,000 eggs in the fall of 1895 from wild fish and hatched a good percentage; also bought 25,000 fry in the spring of 1896.

It soon appeared that conditions were not right for extensive fish-cultural operations, as I had started too near the head of the supply and the water became too warm and stagnant. Some of the ponds contained a number of bottom springs which supported a limited number of fish. By 1897 the reservoir had grown up to a dense mass of moss, which, although it was raked out by the boat load, could not be suppressed.

In February, 1899, there were three weeks of intensely cold weather, which heaved all the raceways and put the ponds out of commission. Early in the spring the remainder of the farm was purchased and a large reservoir constructed at the head of the valley. Here was a water supply of 453 gallons a minute. The reservoir was 277 feet long, had an average width of 58 feet, and an average depth of 3½ feet, and was full of small bottom springs.

In 1900 the pond built in 1895 went out during a severe storm. Meanwhile fry of 1899 had grown to good size and 1,500,000 eggs were taken that fall. Losses during the spawning season were normal.

Early in the spring of 1901 an epidemic broke out among these fish. We could pick up from 40 to 50 dead fish early in the morning, and by evening there would be just as many more. Most of them showed no marks of any kind; a few were fungused. The ponds were thoroughly cleaned and the fish shifted, but there was no abatement of the disease.

About the middle of June the fish were netted and given their liberty in the reservoir and the mortality ceased at once, only seven fish being lost. Here there was plenty of natural food and the fish were not supplied with artificial food. In the early fall they were netted and trapped for breeding purposes and placed in a clean pond, but they commenced to die in large numbers before they had ripened their spawn. It was apparent that they had the boil or ulcer disease, as they were covered with purplish blotches and boils.

The hatch of 1900–1901 proved almost a total loss, caused by water pollutions. Early in 1902 I started to build a new system of ponds down the valley. All the brook trout on hand were disposed of. Two hundred and fifty thousand eggs were purchased from eastern sources that season, a number of flowing wells were installed, and it looked as if the troubles were over. But the sequel proved there were worse. Heretofore the fish had not been attacked by disease until 18 to 24 months old, but now the trouble commenced in the fall following their hatching and continued all winter, culminating in the spring with losses of from 90 to 95 per cent. None of these young fish showed any symptoms of boil disease, but most of them had fungus on the gills and head. Not knowing exactly what the trouble was, I continued to hatch fry from eggs taken from wild fish, but the result always proved the same.

I became thoroughly convinced early in 1904 that brook trout could not be reared on an intensive scale under existing conditions, and so reported to persons interested with me, but after these continual losses they were discouraged and would not take any steps to better conditions.

In 1903, 1904, 1905, and 1906 I lost on an average 50,000 to 75,000 yearlings each season, and as no changes were made in methods matters went from bad to worse. In the spring of 1906 there were left only some 40,000 brook trout fry, and as I was unable through severe illness to give the work personal supervision these shrank by September 1 to 10,000. I then determined not to waste any more time and labor on brook trout until the existing conditions could be altered.

I neglected to state that I had taken on rainbow trout in 1898, and had become by 1906 very successful with these fish.

The reservoir built in 1899 had become more or less filled with liquid muck and decaying vegetation. Tons of algae were taken off each year in the early spring and the water could be seen to work and boil. This would continue

until about June 1, when all the trees had leaved and water cress had grown to good size, then losses in fry would cease until fall.

In the fall of 1906 I secured complete possession of the plant and at once cut out this reservoir, laying dry the ponds it fed, disposed of all brook trout fingerlings on hand and contracted all eggs taken excepting 18,000 eyed eggs from wild stock.

In the spring of 1907 I ordered made a galvanized iron raceway 277 feet long, 18 inches wide, and 5 inches deep. This was put in place about June 10, and fry were placed in the pond about June 15. The water entering the raceway comes some 700 feet across the marsh, through a solid bed of water cress, and is very cold.

The loss in brook trout fry before they left the hatchery had been very slight, and the still smaller losses outdoors were agreeably surprising. In fact, from June 15 to September 15 the total loss was 152 fry. This pond was drawn once a week and thoroughly cleaned. The fish were fed sheep's liver, always absolutely fresh, and the pond was literally alive with water fleas and pond snails. About this time we became so busy with other work that this pond was not cleaned for about four weeks and the result was a loss of 110 fish, which had become fungused, confirming my theories that unsanitary conditions had been the cause of all this waste of fish and time.

These fish were moved and sorted into two ponds farther down and estimated, by counting a series, at 14,000 in number. A finer lot of fry it would be hard to find. They were of a good size and color. I looked forward eagerly to spring, as I was not satisfied that this would be a permanent success. They were again moved and reassorted into larger ponds about April 22, 1908. As a matter of course there is some loss in these fish—kingfishers, herons, snakes, etc., destroying some, and a few dying of disease.

In addition to the above I have about 450 two, three, and four year old fish. The losses in these have been about two fish per month since spawning, last fall. I have kept all of the hatch of brook trout, this season some 75,000. I am thoroughly convinced that they can be reared successfully. In order to accomplish this desirable result the water must be pure and cold, the ponds kept absolutely clean, and the food perfectly fresh and sweet.

I believe that if conditions permit of changing the application of the water supply these results can be obtained at other stations that have had this trouble, provided the water is suitable to start with. At stations which derive their water supply from brooks or ponds that heat and dry up in summer and freeze hard in winter, it will be obvious that the case is hopeless.

In conclusion, I will state that I will be pleased to give personally any further information that may be desired.

AMERICAN FISHES IN ITALY

By Giuseppe Besana

President Lariana Section, Lombardy Society of Fisheries and Aquiculture

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

AMERICAN FISHES IN ITALY.

By GIUSEPPE BESANA,
President Lariana Section, Lombardy Society of Fisheries and Aquiculture.

[Translated from the German.]

REARING IN ARTIFICIAL PONDS.

In the small ponds of the Piscicoltura Borghi at Varano-Borghi, opened in 1907, were produced at first mostly fry and yearling fishes for stocking purposes. But as the plants were without results, the ponds were increased in number and the rearing of table fishes was undertaken, including attempts to cultivate American trouts and salmon, namely, *Salmo irideus*, *Oncorhynchus tschawytscha*, and *Salvelinus fontinalis*. Experiments were made also with *Salmo clarkii*, crossing it with the rainbow trout.

Of these fishes, at the present time only the rainbow trout is being cultivated. The quinnat grew extraordinarily fast during the first year and without losses, reaching a size for table use during that one year; but the flesh was not yet firm nor of good flavor. The growth was still good during the second year, but in the third year there remained but very few of the fish, and they were thin and for the most part died during the period of spawning. The quinnat presented another disadvantage during the second year, being so delicate that when fished out to be transferred to other ponds, in spite of the great care taken, a great number of them died. The brook trout grew very well during the first year, markedly less during the second year, still less during the third, while the mortality continually increased. Compared with the European salmonoids the best results were obtained with the rainbow trout. In the second summer these trout reached the size of table fishes, weighing 150 to 200 grams, and the flesh had a good flavor. They endure transportation well, and readily take artificial food. We know of no other salmonoids so well adapted to culture in ponds. The few experiments in crossing the *irideus* with the *clarkii* trout did not encourge further effort, as the growth of the hybrid is far inferior to that of *irideus*.

PLANTS IN LAKE MANATE.

The area of this lake is 240 hectares; greatest depth, 37 meters; plankton abundant; vegetation scant; maximum temperature of water, 8° C. at the bottom, 24° C. at the surface; minimum temperature, 8° C. at the bottom, 0° C. at the surface. The native fishes of this lake are, in the order of their abundance, river perch, tench, roach, pike, bleak, eel, and burbot. Tables I, II, III, and IV show the plants of the introduced fishes and the catch. Table V gives the catch for 1907.

TABLE I.—RAINBOW TROUT (SALMO IRIDEUS).

Year.	Size or age of fish planted.	Number planted.	Number caught.	Weight of catch.
				Kilograms.
1897	Fishes 2 years old	800		
1898	Small fry	4,130		
1899	Yearlings	8,618		
1899	Fry 2 months old	676	5	9.700
1900	Fry 2 months old	1,400		
1901	Yearlings	300	7	9.800
1901	Fishes weighing 400 grams each	21		
1902	Fry 2 months old	4,500		
1903	Small fry	10,000		
1904	Small fry	10,000		
	Total	40,445	12	19.500

TABLE II.—BROOK TROUT (SALVELINUS FONTINALIS).

Year.	Size or age of fish planted.	Number planted.	Number caught.	Weight of catch.
				Kilograms.
1903	Fry 2 months old	2,240		
1903	Yearlings	80		
1903	Fish weighing 200 grams each	150		
1904	Small fry	2,500	19	5.200
1905	Yearlings	518		
	Total	5,488	19	5.200

TABLE III.—BLACK BASS (MICROPTERUS SALMOIDES).

Year.	Size or age of fish planted.	Number planted.	Number caught.	Weight of catch.
				Kilograms.
1897	Yearlings	500		
1897	Fish 2 years old	86		
1897	Fish 3 years old	6		
1899			30	11.80
1901			76	78.20
1902			226	217.10
1903			163	196.70
1904			372	284.50
1905			343	246.80
1906			803	368.20
1907			241	147.40
	Total	592	2,254	1,550.70

TABLE IV.—SUNFISH (LEPOMIS AURITUS).

Year.	Number of fish planted.	Average weight when planted.	Weight of catch.
		Grams.	*Kilograms.*
1901	140	30	
1901	66	45	
1902	91	50	
1903			120.80
1904			164.60
1905			249.20
1906			300.10
1907			302.70
Total	297		1,137.40

TABLE V.—TOTAL CATCH IN LAKE MANATE IN 1907.

Species.	Number.	Weight.
		Kilograms.
Tench (Tinca vulgaris)	618	706.70
River perch (Perca fluviatilis)		562.80
Small eels (Anguilla vulgaris)	107	22.60
Large eels (Anguilla vulgaris)	24	14.70
Pike (Esox lucius)	53	46.50
Bleak (Alburnus alborella)		302.70
Sunfish (Lepomis auritus)		302.70
Black bass (Micropterus salmoides)	241	147.40
Burbot (Lota vulgaris)	4	1.10
Total		2,107.20

Failures were noticeable with the salmonoids. I must add, however, that I have had similarly negative results with European salmonoids. It was only in the beginning of this year that there were caught 100 *Coregonus marœne*, weighing from 0.50 to 2 kilograms. Fry of this species had been introduced, and a large individual was seen only here and there. No fry had been planted in the lake for four years, and the smaller fishes which were caught, weighing 800 grams, must have been bred from fishes that had spawned in the lake.

The sunfish did not increase greatly in this lake; the catches are insignificant and have never exceeded 300 kilograms yearly, i. e., somewhat over 1 kilogram per hectare.

I had built great hope on the black bass. Young *Micropterus* were seen everywhere during the first years. The first catch was made only four years after their introduction, and it increased to 368 kilograms. During the last year, however, it fell to one-half of this quantity, and the present year will show still poorer results. When the black bass was introduced there were quantities of bleak in the lake, and this fish was not caught at all. At the present time it has entirely disappeared.

Lake Manate yields at present, as formerly, 3,000 to 5,000 kilograms of fish yearly. No benefit was derived from the introduction of new species of fishes,

but perhaps even some disadvantage. *Micropterus*, which bring a higher price, have disappeared, as have also the river perch and the pike, probably on account of a lack of small fishes for food. The tench and the roach (*Leuciscus erythrophtalmus*) are the only ones that remain.

How to provide new food is the present difficult problem, which, after the failure with the sunfish, will scarcely find easy solution with present experience.

PLANTS IN LAKE VARANO.

Area of this lake, 360 hectares; greatest depth, 7 meters; much plankton, very rich vegetation; maximum temperature of the water, 24° C. at the surface, 24° C. at the bottom; minimum temperature, 0° C. at the surface, 6° C. at the bottom.

The species of fish contained in the lake are, in the order of their abundance, sunfish, river perch, tench, bleak, black bass, eel, zander, mirror carp, and pike. The sunfish and black bass, also the zander and the carp, were introduced in this lake.

The results obtained with the American fishes here are marvelous, especially with the sunfish, as two other lakes communicating with Lake Varano are overstocked with sunfish. It is scarcely possible to notice any effect on the other kinds of fishes, except that the pike has grown scarcer and the bleak has disappeared. The river perch is much fatter and grows much more rapidly than before.

The plants of introduced fishes, together with subsequent catches, are shown in tables VI and VII. The yearly output of fish of all kinds, amounting, formerly to 170 tons, has increased to 300 and more tons. Table VIII gives the total catch for 1907, which is exceedingly good, amounting to almost 90 kilograms per hectare.

TABLE VI.—SUNFISH (LEPOMIS AURITUS).

[Eighty-three 3-year old brood fishes introduced in 1900.]

Year.	Weight of catch.
	Kilograms.
1901	682.5
1902	1,919.5
1903	5,845.9
1904	5,958.4
1905	7,456.9
1906	5,990.7
1907	12,811.4
Total	40,665.3

TABLE VII.—BLACK BASS (MICROPTERUS SALMOIDES).

Year.	Fish introduced.			Number caught.	Weight of catch.
	Number.	Size or age.	Average weight.		
			Grams.		*Kilograms.*
1900	8	Brood fish	560		
1900	1,000	Small fry			
1901	21	Brood fish	860		
1902	6	Brood fish	500		
1903				859	657.50
1904				3,193	2,204.90
1905				2,183	1,387.30
1906				8,941	2,987.20
1907				5,896	2,345.70
Total				21,872	9,582.60

TABLE VIII.—TOTAL CATCH IN LAKE VARANO IN 1907.

Species.	Number.	Weight.
		Kilograms.
Tench (Tinca vulgaris)	2,801	3,634.70
River perch (Perca fluviatilis)		7,568.10
Small eels (Anguilla vulgaris)	1,066	280.50
Large eels (Anguilla vulgaris)	894	457.30
Pike (Esox lucius)	224	232.10
Bleak (Alburnus alborella)		2,626.60
Sunfish (Lepomis auritus)		12,811.40
Black bass (Micropterus salmoides)	5,896	2,345.70
Carp (Cyprinus carpio)	52	280.30
Zander (Lucioperca sandra)	219	407.70
Total		30,644.40

I was criticised for introducing the sunfish, but I believe that I do not deserve it. The sunfish is of much better flavor than the ordinary bleak. Delicious steaks can be cut out of the larger of them, and the fish bring a good price where better known. They are also a very good food for the carnivorous fishes in the lake. They increase in an extraordinary manner in shallow lakes and must be fished out diligently. They do not reach any importance in deeper lakes and in consequence can not have any effect. In lakes where there are no salmonoids the sunfish should be an excellent item of popular food. The average weight of the fish caught is 100 grams, which is reached in three years, but we have caught individuals weighing 400 grams. Another advantage is that except when the lake is frozen it is always possible to catch more or less sunfish, a thing which is of great importance to the fisherman. The long spawning season, lasting from May until the middle of August, offers the advantage that, as the sunfish do not grow during the winter, there is present through almost the entire year a quantity of small fishes to constitute a food for the predatory species. If the sunfish now and then eats other small fry, it does not consume dangerously great quantities. That it does not eat spawn is well established. The fish should be of great value in Italy in swampy waters, where it thrives

very well and can stand great heat and great cold. While Lake Manate, which is of far greater depth, produced only a little more than 1 kilogram per hectare, the shallow Lake Varano with its swampy bottom produced 35 kilograms of sunfish per hectare during the past year.

The black bass also flourished in this lake (table VII), yielding somewhat less than 10 kilograms per hectare. The fishing is very irregular and uncertain, however, some 100 kilograms being caught one day, while on the next not one fish may be found. The black bass can be transported safely alive. Its flesh is boneless and very palatable, but its plump shape and big head make its sale difficult. There is much around the head that can be eaten, but most people prefer the zander. The growth of the black bass is markedly greater than that of the river perch. While the latter seldom reaches 1 kilogram and this in some eight or nine years, the black bass reaches this weight in three years. It increased in number considerably during the first years, but later, when there were many large individuals, these ate up many of the smaller of their species. It has no effect whatever on the other fishes in the lake, except *Alburnus alborella*, which it has eaten up entirely. I certainly prefer the zander, but it can not be introduced into all waters, while the black bass will thrive anywhere.

I have also introduced the black bass in small lakes with great success and at a small cost. In order to make this success lasting, however, it is necessary to introduce the sunfish at the same time. The small bleak is soon eaten up by the black bass, the sunfish alone, on account of its enormously prolific propagation, being able to withstand and keep ahead of this terrible devourer.

On account of the defective organization on the part of our government in respect to fisheries, it is impossible for me to report on the introduction of rainbow trout in public waters, or on catfish, black bass, and sunfish in other lakes. It may be seen, however, from the above reports, that great advantages may be reaped from the introduction of these and other American fishes.

ACCLIMATIZATION OF AMERICAN FISHES IN ARGENTINA

By E. A. Tulian

Chief of the Section of Fish Culture, Ministry of Agriculture, Argentina

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

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By E. A. TULIAN,
Chief of the Section of Fish Culture, Ministry of Agriculture, Argentina.

During the latter part of 1903 the Government of Argentina, having determined upon investigations as to the possibilities of practical fish culture in that country, employed Mr. John W. Titcomb, chief of the division of fish culture in the United States Bureau of Fisheries, to inaugurate the undertaking. Mr. Titcomb was engaged in the work some eight or nine months, and during this period arranged for the introduction of several species of fish from the United States. He also chose the site for the first hatchery at Lago Nahuel Huapi, situated in the Andes Mountains, within 2 or 3 miles of the Chilean boundary.

Actual fish cultural work was begun in Argentina March 4, 1904, with the arrival at Lago Nahuel Huapí of a consignment of fish eggs with which I had left New York January 19. From Buenos Aires I brought also the necessary equipment for a small temporary hatchery, the latter having been planned by Mr. Titcomb and nearly finished under his direction before he left the lake. The first part of the journey, from Buenos Aires to Neuquen, was made by train, the time occupied being two nights and one day. From Neuquen to Lago Nahuel Huapí, a distance of 300 miles, the eggs and hatchery equipment were carried in wagons, the members of the party accompanying on horseback.

The consignment of eggs consisted, in New York, of the following: One million whitefish (*Coregonus clupeiformis*), 100,000 brook trout (*Salvelinus fontinalis*), 53,000 lake trout (*Cristivomer namaycush*), and 50,000 landlocked salmon (*Salmo salar sebago*). The loss in the entire lot of eggs, from the time they left New York until their hatching was completed, was less than 10 per cent. The loss in the lake trout was only about 5 per cent, and the same in one lot of brook trout, while the other 50,000 lot of this species began hatching before reaching their destination, thereby causing a loss of about 30 per cent. The loss of landlocked salmon was about 10 per cent, while the loss of whitefish to the day their distribution was concluded had been only 10 per cent. This consignment of eggs produced a great many more fry than we expected, and it became necessary to move the hatching troughs and fish immediately

to a site about 3 miles away, where were found springs from which would flow at least ten times more water than those at the first location. The hatchery on this site has since been pulled down and rebuilt on a much larger scale.

We liberated 900,000 strong, healthy whitefish fry in Lago Nahuel Huapí within a month after the arrival of the eggs at the hatchery. Up to the present time, however, no specimens of the whitefish have been secured for unmistakable identification, owing, probably, to the fact that we have not yet been able to fish systematically for them with suitable boats and nets. A supposed whitefish was caught in a small seine about a year ago by an "estanciero" living on the shore of the lake.

The majority of the lake trout, as also the greater number of the landlocked salmon, were planted in the lakes Nahuel Huapí, Traful, Gutierrez, and Correntosa. Lago Traful is about 45 miles from Lago Nahuel Huapí, and is about 30 miles long, but probably not more than 5 wide at greatest width, and very narrow at other points. Lago Gutierrez and Lago Correntosa are connected with Lago Nahuel Huapí by short streams. Both lakes are about 10 miles long, with an average of 2 to 4 miles in width. The larger proportion of the brook trout were planted in a number of small rivers and streams flowing into these lakes, as well as in tributaries to the Rio Limay and Rio Traful. The Rio Limay flows out of Lago Nahuel Huapí, and the Rio Traful out of Lago Traful, and empties into the Rio Limay.

Lake trout have been found in Lago Traful and Lago Correntosa, and landlocked salmon in Lago Gutierrez, while brook trout have been found in nearly all of the rivers and brooks stocked. In many of these the brook trout are very numerous and are increasing rapidly. The superintendent and assistants of the Nahuel Huapí hatchery took, both last year and this, thousands of fingerlings from irrigating ditches which receive their water from these streams, and replanted them in the brooks. Only last April 860 brook trout fingerlings were taken from a small garden-irrigating ditch heading in the "arroyo de Jones," and 2,300 from another heading in the "arroyo de Newbery." These were undoubtedly fingerlings hatched in September or October, 1907.

On March 1, 1905, the fish in the ponds at the Nahuel Huapí hatchery were counted, and there were found to be 8,500 brook trout, 3,800 lake trout, and 1,800 landlocked salmon. They measured from 6 to 8 inches in length. A large number were accidentally lost during the latter part of the year, but in May, 1906, we had a considerable number of each of these species in the ponds. The death rate in all three from the time hatched, in March, 1904, until now was as low as would have been found at any one of the more successful trout hatcheries in the United States. During this month (May) about 50,000 brook trout eggs were collected from stock fish, and the loss on the lot during the hatching period was but 4 per cent. The alevins hatched were strong

and healthy, and later turned out a robust lot of fry, the loss being less than 5 per cent during the next four months.

During May and June, 1907, 270,000 brook trout eggs were collected at the Nahuel Huapí hatchery. They were hatched with an average loss of 15 per cent. On June 21 140,000 of these eggs were eyed and started down the Rio Limay to Neuquen in a small boat, and brought from Neuquen to La Cumbre, in the Province of Córdoba, via Buenos Aires, by rail. They arrived at the La Cumbre hatchery July 7, with a loss en route of 2 per cent, and were hatched with a further loss of 4 per cent. The fry loss was not large, not taking into account the killing of a large number by accident. Plants of fry were made during the latter part of August and all of September, in various bodies of water in the provinces of Córdoba, Buenos Aires, Tucuman, Salta, and San Luis.

La Cumbre is in the Córdoba Mountains, an inland range, and about eighteen hours from Buenos Aires by train. The elevation is about 4,100 feet.

I have not yet had time to make a systematic investigation of the waters stocked with the fish hatched from the 40,000 brook trout eggs at La Cumbre, but have been told that trout do exist in several of these bodies of water; and I know that splendid results have been obtained from a plant of 200, made the last of September, in what is known as the Lumsdaine "dique." This is a small pond from 130 to 150 feet in diameter, nearly round, with a maximum depth of 10 feet in its deepest part when full, which is seldom. The water for filling this pond is brought from a very small mountain stream in an open ditch, which is from one-half to three-fourths of a mile long and into which the sun shines all day. The minimum flow of this stream is 35 gallons of water per minute, and the ponds receive it all during the first ten days in each month, but only 5 gallons per minute during the rest of the month. The maximum temperature of the water in this stream is 75° to 77° F. at noon on a hot summer's day, but usually drops back to from 60° to 65° F. at night. I do not know the temperature of the water in the ditch where it empties into the pond at midday in summer, but judge it reaches a temperature as high as 80° to 85° F. I presume the temperature of the water in the bottom of the pond is about 74° to 78° F. at this time.

On July 31, 1908, about one year after these trout were hatched, there were in this pond from 125 to 150 as fine and healthy brook trout as I have ever seen. The only artificial food they have ever had was during about one month when held in the rearing troughs. Since being liberated they have had only the natural food found in this pond; notwithstanding which all are now from 7 to 10 inches in length.

It is hoped that about one-half million of brook trout eggs and a few thousand of landlocked salmon eggs will be collected at the Nahuel Huapí hatchery this

season. By May 31 a total of 255,600 brook-trout eggs had been secured. About the first of June 63,000 eyed eggs of this lot were sent to Buenos Aires, and from this city 23,000 were sent to the La Cumbre hatchery, and 40,000 to a small temporary hatching plant only recently located near Ledesma, in the Province of Jujuy, the most northerly province of Argentina. A few days later another lot of 25,000 brook trout eggs were shipped from the Nahuel Huapí hatchery to Santiago, Chile, by request of the Chilean Government, to be hatched in a small hatchery belonging to that Government, located in the Andes Mountains, on the railroad which crosses from Buenos Aires to Valparaiso, not far from the Argentine boundary. The eggs shipped to La Cumbre and Ledesma, via Buenos Aires, reached their respective destinations with a loss of less than 3 per cent. Those shipped to La Cumbre were hatched with a very small loss (less than 4 per cent), and the alevins are strong and robust and fast reaching the feeding stage, with a very small percentage of loss. The loss of eggs hatched at Ledesma was larger, owing to the high temperature of the water we were compelled to use for hatching, which was 55° to 60° F., and 8° to 10° F. warmer than at La Cumbre. The loss of alevins at Ledesma has also been rather large to date, owing probably to the same cause; in neither case, however, has the loss been unexpectedly great.

From what we have accomplished with the brook trout at Nahuel Huapí and La Cumbre, I am led to believe that, by gradually breeding them up to it over a period of two or three years, these fish can be successfully reared in very warm water.

The following table shows the small loss of stock fish at the Nahuel Huapí hatchery for the five months ended March 31, 1908:

STATEMENT OF LOSSES OF ADULT FISH AT NAHUEL HUAPÍ HATCHERY FOR FIVE MONTHS ENDED MARCH 31, 1908.

Species.	On hand Oct. 30, 1907.	Deaths from Oct. 30, 1907, to Mar. 31, 1908.	On hand Mar. 31, 1908.
Brook trout (2 to 4 years)	4,902	53	4,849
Landlocked salmon (4 years)	70	3	67
Rainbow trout (3 years)	4		4
Total	4,976	56	4,920

Of fingerling and yearling brook trout there were on hand October 30, 1907, 60,950; distributed November 1, 1907, to March 31, 1908, 49,700; loss November 1, 1907, to March 31, 1908, 3,350; on hand March 31, 1908, 8,900.[a]

The second shipment of eggs of American fishes to the Argentine Republic resulted rather disastrously. One of the superintendents of this section left New

[a] It is in the summer months—December, January, and February—covered by these figures, that the greatest losses occur.

York early in June, 1904, with 20,000 eggs of steelhead trout (*Salmo gairdneri*) and 50,000 rainbow trout (*Salmo irideus*) eggs. Off the coast of Brazil the steelhead eggs commenced hatching rapidly and before reaching Rio Janeiro these had all to be put overboard. The rainbow trout eggs carried very badly, and nearly all were lost by July 23. On this date the few remaining live eggs were planted in Laguna La Grande, as it was deemed impossible to reach the Nahuel Huapí hatchery with any alive.

The third shipment was more successful, although far from satisfactory. Early in January, 1905, one of our superintendents left New York with 300,000 brook trout (*Salvelinus fontinalis*) eggs, 224,000 lake trout (*Cristivomer namaycush*), 100,000 quinnat salmon (*Oncorhynchus tschawytscha*), 92,000 rainbow trout (*Salmo irideus*), and 30,000 landlocked salmon (*Salmo salar sebago*), arriving in Buenos Aires February 4. On arrival in the city, the quinnat salmon eggs were found to be practically all dead, while the larger portion of rainbows were either dead or dying. The landlocked salmon, brook and lake trout were in much better condition, the percentage of loss en route having been comparatively small. The greater portion of the live eggs were taken to the Nahuel Huapí hatchery, where they were hatched with fair success. An attempt was made, however, to hatch a few landlocked salmon, brook and lake trout eggs in a temporary hatching plant erected at Alta Gracia, in the Province of Córdoba. The water to be used was from a small mountain stream, it being hoped that the weather would be sufficiently cold at this time—the latter part of March—to reduce the water temperature here to about 55° F. Unfortunately, however, the weather proved to be as warm as at any time during the entire summer, and consequently the water temperature in this stream would rise to about 75° F. at midday, although usually falling to about 60° F. each night. The hatching plant had been located where there were two small springs whose waters came out of the ground at 62½° F. This water was to be given a trial in case the water in the stream was higher, but water at 62½° F. was found to be entirely too warm for hatching and rearing eggs which had been in refrigerator cases at a temperature of 35° to 38° F. for nearly eighty days. A few thousand fish of each variety were hatched, but had to be planted soon after coming out. It has been reported that some of the trout and landlocked salmon planted here have been caught from time to time, but I have never been able to obtain a specimen of either.

The fourth shipment yielded even better results than the first. On February 10, 1906, I left New York, en route to Argentina via England, with 300,000 quinnat salmon (*Oncorhynchus tschawytscha*) eggs, 122,500 sockeye salmon (*Oncorhynchus nerka*), 98,200 silver salmon (*Oncorhynchus kisutch*), 80,000 lake trout (*Cristivomer namaycush*), 60,000 brook trout (*Salvelinus fontinalis*), 30,000 landlocked salmon (*Salmo salar sebago*), and 25,000 rainbow trout (*Salmo

irideus). At Southampton, England, on February 23, I received 25,000 Atlantic salmon (*Salmo salar*) eggs from the Earl of Denbigh's fisheries in North Wales. On March 17 I arrived at Buenos Aires, but I was unavoidably delayed here for 10 days. The losses from the time the eggs were packed at the hatcheries in the United States and North Wales until reshipped on March 27, en route to the Santa Cruz hatchery, in southern Argentina, were as follows: Quinnat and sockeye salmon, 1 per cent each; brook and lake trout, the same; silver and landlocked salmon, 2 per cent each; Atlantic salmon, only 5 per cent, while it was 20 per cent on one lot of rainbow and 60 per cent on another. From this time until all of the eggs were hatched, April 30, the losses of eggs and alevins were as follows: Quinnat and silver salmon, only 2 per cent; sockeye salmon, 4 per cent; lake trout and landlocked salmon, only 5 per cent; brook trout, 20 per cent (mostly fish hatched en route because of the delay in Buenos Aires), and Atlantic salmon and rainbow trout, about 50 per cent.

The following table shows the number of each species on hand at the Santa Cruz hatchery May 1, 1906, and again on November 1, 1906, with losses, plants made, etc., during this period (6 months):

RECORD OF SANTA CRUZ HATCHERY, MAY 1 TO NOVEMBER 1, 1906.

Species.	On hand May 1.	Deaths May 1 to Nov 1.	Per cent of loss.	Distributed May 1 to Nov. 1.	On hand Nov. 1.
Quinnat salmon	291,000	8,730	3	270,470	11,800
Sockeye salmon	116,400	2,330	2	110,470	3,600
Silver salmon	94,300	4,715	5	85,185	4,400
Lake trout	75,200	2,250	3	68,550	4,400
Brook trout	47,500	2,850	6	40,050	4,600
Landlocked salmon	27,90c	3,070	11	24,040	790
Rainbow trout	9,400	750	8	8,400	250
Atlantic salmon	11,900	5,900	50	6,000	----------
Total	673,600	30,595	----------	613,165	29,840

The following table shows the number of each species on hand at the Santa Cruz hatchery on November 1, 1906, and again on March 1, 1907, with losses, plants made, etc., during this period (4 months):

RECORD OF SANTA CRUZ HATCHERY, NOVEMBER 1, 1906, TO MARCH 1, 1907.

Species.	On hand Nov. 1.	Deaths Nov. 1 to Mar. 1.	Per cent of loss.	Distributed Nov. 1 to Mar. 1.	On hand Mar. 1.
Quinnat salmon	11,800	165	1.4	7,000	4,635
Silver salmon	4,400	22	.5	1,300	3,078
Sockeye salmon	3,600	20	.56	----------	3,580
Brook trout	4,600	65	1.4	----------	4,535
Lake trout	4,400	36	.8	----------	4,364
Landlocked salmon	790	87	11.0	----------	703
Rainbow trout	250	13	5.0	----------	237
Total	29,840	408	----------	8,300	21,132

The following table shows the number of each species on hand on March 1, 1907, and again on October 1, 1907, with losses and plants made during this period (7 months):

RECORD OF SANTA CRUZ HATCHERY, MARCH 1 TO OCTOBER 1, 1907.

Species.	On hand Mar. 1.	Deaths Mar. 1 to Oct. 1.	Distributed Mar. 1 to June 1.	On hand Oct. 1.
Quinnat salmon	4,635	4	4,135	496
Silver salmon	3,078	8	2,578	492
Sockeye salmon	3,580	47	3,078	455
Brook trout	4,535	25	693	3,817
Lake trout	4,364	57	983	3,324
Landlocked salmon	703	64	499	140
Rainbow trout	237	15		222
Total	21,132	220	11,966	8,946

The Santa Cruz hatchery is supplied with water from two springs, which do not run more than 125 gallons of water per minute, at a temperature of 48° F. When the shortage of this water supply is considered, it is little less than remarkable that we were able to hold the large numbers of 6 months old fish (about 30,000, the greater number being Pacific coast salmon) which we had on hand November 1, 1906 (see first table), and have them in a perfect state of health on this date. In fact they were as healthy as possible on October 1, 1907, one year and six months after they were hatched. The very low death rate from November 1, 1906, to October 1, 1907, will be found by referring to the last two tables. The water supply of the Santa Cruz hatchery decreased greatly during the summer of 1907–8 (months of December, January, and February), and the fish on hand showing signs of disease, a number of each species were planted during these months.

On January 18, 1908, the fifth lot of eggs brought from the United States to Argentina left New York, numbering as follows: 300,000 quinnat salmon (*Oncorhynchus tschawytscha*), 104,000 sockeye salmon (*Oncorhynchus nerka*), 90,000 silver salmon (*Oncorhynchus kisutch*), 75,000 lake trout (*Cristivomer namaycush*), 75,000 brook trout (*Salvelinus fontinalis*), 30,000 rainbow trout (*Salmo irideus*), 15,000 landlocked salmon (*Salmo salar sebago*), and 3,000,000 cod (*Gadus callarias*). I personally had charge of this consignment of eggs to Southampton, England, being accompanied by Mr. Frank Brophy. The loss of the cod eggs was almost complete when we arrived in England, hence I determined not to attempt to take any of these farther. The loss of other eggs was very small indeed, having been less than one-half of 1 per cent from the time they were packed until put on board the steamship *Thames* on January 30, en route to Buenos Aires. The eggs were given over to Mr. Brophy's charge when this ship left her dock on January 1, and in addition to those already mentioned

he was given 20,000 Atlantic salmon eggs which were secured from the Earl of Denbigh's fisheries in North Wales. Mr. Brophy arrived with the eggs at the hatchery in Santa Cruz on March 1. The loss from the time of leaving Southampton until the eggs were unpacked at the hatchery was as follows: Quinnat salmon, a little over three-fourths of 1 per cent; sockeye salmon, a little over $1\frac{7}{10}$ per cent; silver salmon, a little less than nine-tenths of 1 per cent; lake trout, something over three-fifths of 1 per cent; brook trout, somewhat over two-fifths of 1 per cent; landlocked salmon, a trifle over $1\frac{1}{2}$ per cent; rainbows (youngest packed without moss) about $30\frac{2}{5}$ per cent; rainbows (youngest packed in moss), a little less than 64 per cent; rainbows (oldest packed without moss), $5\frac{3}{5}$ per cent; rainbows (oldest packed in moss), a trifle over $6\frac{1}{5}$ per cent; and Atlantic salmon 100 per cent. The total loss of the Atlantic salmon was due to imperfect packing, which was not discovered until after the eggs were all injured.

While the eggs that reached the hatchery alive appeared to be good, they were not as strong as a similar lot brought out for this hatchery from the United States and England two years previously, as will be seen by a comparison of the records. The death rate from the time the eggs were put into the hatching trays until they had finished hatching was in most cases rather high, as was also the death rate of fry during the month of March. The losses of eggs during the hatching period were as follows: Quinnat salmon, −9 per cent; blueback (sockeye), 30+ per cent; silver salmon, −14 per cent; landlocked salmon, 4+ per cent; brook trout, 34+ per cent; lake trout, 17+ per cent; and rainbow trout, −44 per cent. The losses of alevins during the month of March was as follows: Quinnat salmon, 5+ per cent; sockeye salmon −9 per cent; silver salmon 18+ per cent; landlocked salmon −63 per cent; brook trout, 10+ per cent; lake trout, −27 per cent; and rainbow trout, 100 per cent.

The lake trout from this hatchery and also the landlocked and sockeye salmon are planted in Lago Argentino and other bodies of water near by. The other salmon are usually planted in the Rio Santa Cruz and tributaries and Rio Gallegos and tributaries. The brook trout are planted in tributaries to the rivers mentioned, also in the tributaries of Lago Argentino and Lago San Martin. The rainbows (first lot of eggs) were planted in tributaries to the Rio Santa Cruz. Lago Argentino is supplied by several small rivers and streams which rise in the Andes Mountains, where there is ice and snow the entire year. The Rio Santa Cruz rises in Lago Argentino, which itself is situated in the Andes Mountains at an elevation of 2,500 to 3,000 feet above sea level, and is very deep. This lake has not yet been accurately surveyed, but is supposed to be 25 to 30 miles long at its greatest length and from 6 to 8 miles wide. It is in the Territory of Santa Cruz, which is the most southerly but one of Argentina.

On May 6 of this year I left New York with about 300,000 steelhead trout (*Salmo gairdneri*), these being the sixth lot of eggs to leave the United States for the Argentine National Government. These eggs were taken to Southampton, England, where 50,000 rainbow eggs from Germany were added to the consignment. They left England May 15, arriving in Buenos Aires on June 7, and at the La Cumbre hatchery on the 13th of the same month. The loss of eggs en route from the United States was very small, and not over 10 per cent on the rainbow eggs from Germany, this latter loss being entirely due to rough handling between Germany and England in the absence of any attendant. From England to the La Cumbre hatchery the loss was less than one-half of 1 per cent. The loss of the oldest steelhead eggs during the hatching was $6\frac{3}{5}$ per cent, mostly due to these eggs being a trifle too far advanced when shipped. The loss of the second oldest steelhead eggs during the same period was about $15\frac{1}{2}$ per cent, due greatly to the eggs being a trifle young when packed. The loss of the youngest of this lot of eggs while hatching was $18\frac{4}{5}$ per cent, due also, no doubt, mostly to the fact that the eggs were rather young for packing. There is, however, no way to avoid these losses on journeys of this length, as some eggs must be shipped when younger than others to guard against the possibility of the older eggs hatching en route. The loss of steelhead fry until they were six weeks old was 4 per cent. At this age they were as strong and healthy a lot of young trout as I have ever seen. All were feeding at this time.

The loss of the rainbows during the hatching period was about $10\frac{1}{2}$ per cent, and the loss of fry until six weeks old was $2\frac{3}{5}$ per cent. At six weeks of age these were all taking food, and were very healthy and strong.

INTRODUCTION OF AMERICAN FISHES INTO NEW ZEALAND

By L. F. Ayson

Chief Inspector of Fisheries for New Zealand

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

INTRODUCTION OF AMERICAN FISHES INTO NEW ZEALAND.

By L. F. AYSON,
Chief Inspector of Fisheries for New Zealand.

At the commencement it is, I think, appropriate to say something about the geographical position and physical features of this little country in the far away South Pacific, which is doing much valuable work for its people by the introduction into its waters of a number of the best sport and commercial fishes from the Northern Hemisphere.

New Zealand, situated between latitudes 34 and 47 degrees south, in the Pacific Ocean, consists of three main islands, the total area of which is about 104,000 square miles. A large extent of the country is mountainous, particularly in the Middle Island, which is intersected along almost its entire length (about 500 miles) by a range of mountains known as the Southern Alps, the highest peak, Mount Cook (the Maori or native name is "Aorangi," meaning "cloud piercer"), being 12,400 feet. The summer snow line on these mountains is about 7,000 feet above sea level.

As would be expected from a country with such physical characteristics, New Zealand possesses a very fine system of rivers and lakes. In the South Island the larger rivers all originate among snow-clad mountains of hard rock formations; in a good many instances their tributaries flow into mountain lakes and from there down through the low country into the sea. Over 20 rivers, taking their rise among the glaciers of the Southern Alp range, flow down into the Pacific Ocean on either coast. In parts of the North Island the same formations prevail to a large extent, but many of the rivers run for the greater length of their course through low country.

This country, with its unique flora and fauna, has also the extraordinary peculiarity that with its magnificent water system it has no indigenous fresh-water fishes of any sporting or commercial value. Eels (*Anguilla australis*) are found everywhere, also a few inferior fishes, such as the kokopu (*Galaxias fasciatus*); but the only representative of the Salmonidæ is the little smelt (*Retropinna richardsoni*) and the native grayling (*Prototroctes oxyrhynchus*),

called by the natives "upokororo." This interesting fish, however, seems to be on the verge of extermination, owing to the introduction of trout into the rivers it inhabits, to mining, and to clearing of the vegetation from the banks of the rivers for farming purposes.

The early colonists who emigrated to New Zealand from Great Britain were very much surprised to find a country with such fine rivers, lakes, and streams, but with no fish of any value in them. In a few years the question of introducing some of the British Salmonidæ was considered, and in 1864 the matter assumed definite shape when the Otago Provincial Council took it up and voted a sum of money for the importation of Atlantic salmon eggs (*Salmo salar*), and in 1868 the first lot of English brown trout (*Salmo fario*) eggs arrived in the colony. Since that time the English brown trout and the Loch Leven trout (*Salmo levenensis*) have been successfully acclimatized, and the brown trout now abounds in many of the rivers, particularly those in the South Island.

Of American fishes the following species have been brought into New Zealand: Rainbow trout (*Salmo irideus*), eastern brook trout (*Salvelinus fontinalis*), whitefish (*Coregonus clupeiformis*), chinook salmon (*Oncorhynchus tschawytscha*), sockeye salmon (*O. nerka*), landlocked salmon (*Salmo sebago*), Mackinaw trout (*Cristivomer namaycush*), lake herring (*Argyrosomus artedi*), and catfish (*Ameiurus vulgaris*). Of these we have successfully acclimatized the rainbow trout, brook trout, and the catfish, and as the chinook and sockeye salmon have now returned from the sea to spawn three seasons in succession, I think that we can fairly claim that they are established as well.

The following account of the introduction of the fishes mentioned above may be of interest:

Rainbow trout.—Three consignments of eggs were obtained from California by the Auckland Acclimatization Society in 1883 and 1884. These, I believe, were the only rainbow eggs which have been brought to this country. A considerable percentage were lost on the voyage down, but sufficient were saved to provide a stock of brood fish for the hatcheries, and a number to plant in some of the northern rivers. It took some years to work up a stock of spawners at the hatcheries, and as the young fish were produced they were planted in streams all over the Auckland province. It is about fifteen years since rainbow trout commenced to be caught by anglers, and now they exist in immense numbers in almost all the rivers, lakes, and streams in that part of the country.

These fish grow to a great size in this country. While the most common weight caught by anglers is from 2 to 8 pounds, specimens are frequently taken ranging from 10 to 18 pounds, and occasionally over 20 pounds. On the walls of my office I have six mounted specimens taken in the spawning season from a stream flowing into Lake Tarawera; the smallest of these is 12 pounds and the largest 18 pounds. Heavier specimens could have been procured, but these

were chosen on account of their elegant shape. They are most plentiful in the streams flowing into and in Lakes Rotorua and Rotoiti. By angling (and anglers are restricted to 30 pounds weight a day) over 20 tons of trout have been taken out of these two small lakes this season. Rainbow-trout fishing has now become one of the chief attractions for tourists to the Rotorua district, and the value of this fish to the country, both for sport and food, is immense.

Eastern brook trout.—The first brook-trout eggs brought to this country were imported by a Mr. Johnson, of Christchurch, in the South Island, about 1882, and from Mr. Johnson's importation various acclimatization societies obtained eggs from which they subsequently raised stock fish for their hatcheries. From these hatcheries large numbers of young fish of various sizes have been planted in streams both in the north and south. They made a good showing in a few streams for a time, but since the introduction of the rainbow and English brown trout into these streams the brook trout in some instances have wholly disappeared and in others have been greatly reduced in numbers. Our people think highly of this beautiful fish and are much disappointed because better success has not attended the efforts made to thoroughly establish them in our waters.

Chinook salmon.—The first importation of eggs was made in 1875 and from that date to 1880 several shipments were made, some by the Government and some by acclimatization societies. On arrival the salmon eggs were parceled out to different acclimatization societies and the young fish when hatched were planted in rivers from the north of Auckland to the far south. Through want of experience, unsuitable water at the hatcheries, and planting the young fish in rivers when the conditions were entirely unsuitable for them, no results were obtained from these shipments.

In 1900 the government decided to make a vigorous and systematic effort to acclimatize this fish. A site for a salmon station was chosen on the Hakataramea River, a tributary stream of the Waitaki, and the erection of the hatching shed was commenced in November of that year. The government decided to confine its efforts to one of the rivers considered to be the most suitable for these fish, and the Waitaki was chosen, as in its general characteristics it bears a considerable resemblance to the rivers on the Pacific coast of America which the chinook salmon frequent in the spawning season.

In January, 1901, the first shipment of chinook eggs for the government salmon station arrived. They were supplied by the United States Bureau of Fisheries, from its station at Baird, California, on the McCloud River. The shipment came over in charge of Mr. G. H. Lambson, superintendent of the Baird station, and arrived in excellent condition.

From 1901 to 1907 five importations of eggs were made, invariably arriving in splendid condition, the loss in most of the shipments not amounting to more

than one-half per cent, i. e., 99½ per cent of good eggs were unpacked into the hatching boxes at Hakataramea. The total number of eggs in the five shipments reached about 2,000,000, and from these fully 1,700,000 young fish have been turned out. They were planted at various ages from fry to 2-year-old fish, but about 90 per cent were planted just after the sac was absorbed.

Now, as regards the definite results obtained from the young salmon planted. In 1905 salmon were reported as having been caught by anglers in the tideway near the mouth of the Waitaki River, and a specimen of these fish was identified by the late Sir James Hector as a male of the genus *Oncorhynchus*. In May and June, 1906, salmon were found spawning in the Hakataramea River, and specimens were identified by Sir James Hector and myself as chinook. In April and May last year (1907) quite a run of salmon came up the Waitaki River and spawned in several of its main tributary rivers. In the Hakataramea from 300 to 400 salmon spawned in the 2 miles of river before it joins the Waitaki, and a number of these fish were caught and stripped and about 30,000 eggs put down to hatch. The eggs hatched out well, and a number of the young fish are now being reared at the salmon station for experimental purposes. This season the run of spawning salmon in the Waitaki is similar to last year as to quantity, but on an average the fish are considerably heavier, and they seem to have run higher up the main tributary rivers of the Waitaki. Several dead and "spent" fish measured from 3 feet to 3 feet 10 inches in length. Owing to floods when the best run was on, we were able to collect only about 50,000 eggs this season. From the knowledge now acquired with regard to the run of fish in rivers farther inland, arrangements will be made to collect eggs on several streams next season. A point which will be interesting to salmon authorities is that as far as we have gone we have had no "summer" run of salmon; they have always come in April, May, and June—months which correspond, as regards season, with November, December, and January in the northern hemisphere, and the months when the "winter" run of chinook salmon takes place in the Sacramento. Now, I understand that the five shipments of eggs imported to this country from 1900 to 1907 were all from "winter" run fish, and so far we have only had a "winter" run of spawning salmon here.

Sockeye salmon.—Only one importation of sockeye eggs was made to this country. A shipment of 300,000 was presented to the New Zealand government by the Canadian fisheries department in 1902. Most of the young fish were planted in streams flowing into Lake Ohau, a lake fed by rivers flowing down from the snowy Southern Alp Range. In 1905 and 1906 reports were received of salmon spawning in the rivers at the head of Lake Ohau, but we were not able to procure specimens until the "run" which took place in April last year.

The officer who visited the locality reported having seen a large number of dead salmon. He netted a number of fish and brought six specimens, the examination of which by experts proved them to be sockeye.

Whitefish.—The first shipment of eggs was brought from America in 1877, and from that year to 1904 several shipments were brought over. Owing to the want of expert attention on the voyage, these shipments generally arrived in indifferent condition, and as none of the hatcheries had proper appliances for hatching the eggs I am afraid that most of them were killed. In 1904 the New Zealand government determined to make a systematic effort to acclimatize this fish and erected hatcheries, equipped with the proper whitefish hatching jars, on Lakes Te Kapo and Kanieri. Four shipments of eggs were brought over from 1904 to 1907, and as they were carefully packed and selected for the journey and came over in charge of an expert they all arrived in perfect condition. The loss from the time they left the hatchery at Northville, Mich., until put in jars in the hatcheries in New Zealand was under 3 per cent. The total number of eggs in these four shipments was about 6,000,000. The young fish were all planted in the lakes as soon as the sac was absorbed. As there is no netting for fish in these lakes no reliable information has yet come to hand as to whether they have done well or not, but we intend to net them early in the summer this year, for the purpose of proving whether or not they have taken a hold there.

Landlocked salmon.—One shipment of the eggs of these fish was brought to this country in 1906 and arrived in good condition. A number of the young fish have been planted in one of our lakes, and some are now being reared at two hatcheries for the purpose of procuring eggs from them when they mature. There is little doubt but what a good many of our lakes should be suitable for this fish.

Mackinaw trout.—A shipment of Mackinaw eggs was brought over from America in 1906 and they hatched out well. The young fish were planted in lakes in Canterbury and the west coast of the South Island.

Catfish.—A number of these fish were brought over from America by Mr. T. Russell, of Auckland, in 1877. They were placed in St. Johns Lake and are reported as being numerous in that lake at the present time.

The value of the introduction of these foreign fresh-water fishes into New Zealand waters can not be estimated. Formerly it was a country whose rivers and lakes were devoid of fresh-water fish of any value, now they are teeming with fish of the finest quality for sport and food. All this has been attained partly by the perseverance of our own people and by the generous assistance given to our Government by the United States Bureau of Fisheries and its officers in supplying any fish eggs required.

DISCUSSION.

Mr. H. STEPHENSON SMITH. I would like to add, with your permission, sir, as New Zealand is a country very remote from this, and as many, perhaps, of my hearers do not know much about its geographical and topographical features, that the country covers approximately 15° of latitude, almost due north and south. It has over 5,000 miles of seaboard; it is interspersed with water courses. In a large portion of that country you will find a mountain stream every mile. We have also some arterial rivers, running 400, 500, 600, and 700 miles, in some cases navigable short distances from the mouth, and they are all tidal rivers. The majority of the smaller streams which run into the eastern and western streams are not tidal rivers, but are fed by glaciers from the mountains. The whole seaboard is indented with bays and harbors, the rivers coming down on each side; and the lakes extend from one side of the islands to the other. Some of the rivers are of considerable size for a country of that extent; and we have chains of lakes running for hundreds and hundreds of miles.

It would seem to me, as a man who knows little about fish except to eat them, that that country should afford facilities for producing fish of the very best kind and of almost any quantity. It also seems to me that there is plenty of food for the fish. The surface of the lakes and streams is covered with flies and many varieties of little insects all the year around; and the rivers never run dry, but are everlasting streams, winter and summer. I thank you very much for your kind attention.

Mr. JOHN W. TITCOMB. One thought suggests itself to me: The results from the acclimatization of the chinook salmon perhaps are the most remarkable thing in the paper; but it is said that the rainbow trout, so-called, which is so very generally distributed now in New Zealand, is not the rainbow trout (*Salmo irideus*), but the steelhead trout (*Salmo gairdneri*).

Prof. EDWARD E. PRINCE. My name was down, I believe, for a communication a day or two ago, but my engagements officially have been so very pressing that I have with difficulty arrived even at this late hour. If you will permit me, I wish to bring a fraternal message from Canada to this important gathering, and I take this first opportunity of doing so.

One important reason why I would like to say a few words in regard to Mr. Ayson's paper is because I have been personally interested in this work of Mr. Ayson in New Zealand. He has several times visited Canada, and I have spent a good deal of time with him on those visits. I arranged for supplies of salmon eggs to be shipped to that distant part of the world, and I have always felt, as every fish culturist on this continent has, a very warm regard for him and his fishery work.

To sum up the great success of these efforts in New Zealand: Its rivers correspond in many features with those of the Pacific coast; many of them are glacial and have abundance of snow water, and there are other features which Mr. Smith referred to in the few remarks he made which correspond to the waters on this continent. But it seems that on the whole the planting of salmon has not been so successful as the trout, and it has always seemed to me one reason was in the lack of proper feeding grounds. There may be abundant food for them in the streams where they were planted as fry, but when out at sea they are literally "at sea;" they do not know where to go to get the appropriate food

which the salmon gets in the sea. When the salmon get out to sea they do not apparently find their way back again. Whether they find feeding grounds I do not know. The conditions are not the same off the coasts in the seas of New Zealand as off our own coast or the coast of Europe. But the trout do not wander far on the coast, and numbers remain in the rivers and lakes. They have really succeeded marvelously, so that fish whose original parents were only one or two pounds when adult, now reach twenty or thirty pounds in New Zealand (which is a size that would be almost incredible had we not abundant proof of it) under the favorable conditions provided in antipodean waters.

I have had a communication from Mr. Ayson, jr., within the last few days, in which he expresses hope that the sockeye salmon will be a success. If so, and these Pacific sockeyes breed, then I think the trouble for New Zealand salmon is solved.

I have listened with great interest to this paper, and have only to apologize for troubling the meeting with these remarks at this late stage of the discussion.

NATURALIZATION OF AMERICAN FISHES IN AUSTRIAN WATERS

By Franz von Pirko

President of the Imperial and Royal Austrian Fishery Society

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

NATURALIZATION OF AMERICAN FISHES IN AUSTRIAN WATERS.

By FRANZ VON PIRKO,
President of the Imperial and Royal Austrian Fishery Society

In the belief that it might greatly interest American fish breeders to know what experiences and observations have been made by Austrian pisciculturists in regard to fish imported from America for breeding purposes, and in compliance with a special invitation from the committee of the Fourth International Fishery Congress, Washington, 1908, the Imperial and Royal Austrian Fishery Society has called upon the prominent fish breeders to furnish their observations regarding the results obtained with such American fish. These results, which are briefly set forth here, warrant the conclusion that of all the Salmonidæ which can be taken into account for breeding purposes the American rainbow trout must be regarded as the most important. This trout, which has now been in Austrian waters for a quarter of a century, despite manifold opposition has gained, so to say, the rights of citizenship there. Owing to its excellent qualities it has been quickly introduced into all pond fisheries and is really a first-class salmonid. In consequence of its ability to endure deep water, the number of ponds in which it can grow is quite considerable, and pond-fish owners would be well advised to allow plenty of room for the rainbow trout, without forgetting, however, that after all it is a salmonid. Its capacity to stand high temperatures enables it to replace the pike in carp ponds, the more so as it does not possess the dangerous qualities of the latter.

The *irideus* is just as indifferent to high temperatures as to cold. Therefore at a time when the *Salmo fontinalis*, or brook char, and the native brook trout have long ceased to take food the *irideus* still comes to its meals, and the advantage offered to the breeder by its appetite, displayed even when the pond is covered with ice, must not be underestimated. In addition to this its power of resistance against diseases is amazing. It is not only—perhaps owing to its perceptibly thicker skin—far less exposed to the attacks of the malignant Saprolegniaceæ than all the other Salmonidæ, and therefore very rarely seized with fungus, but it also appears to possess immunity from the most dangerous bacterial diseases, such as furunculosis. Its indifference to polluted waters enables it to live in water

courses where no other salmonid could thrive. Even in the immediate neighborhood of factories discharging waste water and refuse, where both the brook trout and the char could certainly not exist, the *irideus* flourishes and grows fat. It appears to be specially valuable for exclusively or partially populating the numerous cold ponds in the forests of lower Austria, which in consequence of their low temperature, severe climate, and exposed situation are less adapted for carp breeding. Altogether it must be said that the *irideus* has fully come up to all that has been expected from it in nearly every instance.

Thus until very recently all breeders joined in a panegyric of the *irideus*. But things have now changed. The sad discovery has been made that the much-praised power of resistance of the rainbow trout in ponds against disease rapidly decreases and that this fish if strongly fed nowadays suddenly shows a remarkable frailty, nay an exotic weakness, which had been entirely unforeseen. The most unpleasant phenomenon for the breeder is the increasing spread of anæmia, which frequently causes great losses. The extraordinary weakness becomes manifest in the death of numerous fish through simple sorting operations, the clearing out of ponds, or short transportation. Quite frequently examination of the dead fish reveals no other symptoms but those of a greater or less poorness of blood. The fish are pale, particularly in the gills, the regular color of which ought to be a very bright red. The internal organs are also pale, and the liver yellow. This organ frequently shows fatty degeneration and is interspersed with hemorrhages, as the result of ruptures of the sides of the vessels. Searches for any other causes, such as bacteria and parasites, have proved unsuccessful. Consequently anæmia must be regarded as a symptom of general deterioration of the breed. As a rule these symptoms become visible in the second year, and it may be that frequently the death of the fry as well as the outbreak of dropsy of the yolk sacs is due to this circumstance. As a matter of course such fish are not very well qualified to act later as mother fish, as they give bad eggs and sometimes remain sterile because of degeneration of the sexual organs. Undoubtedly the unfitness of the rainbow trout for acclimatization here is the cause of this degeneration. The conditions in which the fish lives in its native country, where it migrates even at the spawning time, are it appears different from those in Austria. It may therefore be truly said that the rainbow trout is decreasing at a rapid rate and before long will disappear from our ponds, unless there is a speedy introduction of fresh blood by the importation of eggs from America. In the unfortunately somewhat limited number of brooks and small rivers which for some time have been stocked with *irideus* in a regular and rational manner, a good stock has developed which spawn in open water and multiply in a natural way although not in great numbers. These do not show any of the symptoms of degeneration of the pond and fattened fish of this species.

Not less valued than the rainbow trout was the American brook char, *Salvelinus fontinalis*. It is true it was less utilized than the *irideus*, as it can only live in spring water; its breeding gave very satisfactory results, however, in the first years after its introduction. Not inferior to the *irideus* as regards early growth, it behaved excellently even in ponds watered exclusively by precipitation of the atmosphere and it appeared as though the brook char might be qualified to replace our brook trout, whose breeding offers far greater difficulties. In the course of time, however, these sanguine expectations gave place to bitter disappointment, and it became obvious that all the hopes entertained were chimerical.

Even before birth the char causes great trouble. The losses in eggs are enormous, as despite scrupulous attention at spawning time the number of sterile eggs is great beyond measure, and miscarriages are far more frequent than with other fish. On the other hand, it is true that the bringing-up of the brood gives very little trouble. The small fish take artificial food very early and in autumn the pond is alive with fry. But soon an unpleasant feature becomes visible, viz, premature growth, which attribute is the more unfortunate as the char indulges in cannibalism more than any other fish. In this respect it comes very near the pike. Its voracity very greatly promotes its growth in the first and second years, but later it suddenly stops growing and fine large fish are seldom seen.

Its capacity to resist disease, which quality we value so highly in the *irideus*, is extremely small. Bacterial infections, fungus, and intestinal disorders often kill whole stocks, and it is also much more liable to furunculosis than is its American brother. Besides, the char suffers from a peculiarly special form of petechial affection. This manifests itself in irregularly shaped flat defects of the surface skin, dull gray spots with byssus, the origin of which has not yet been definitely ascertained. This disease has discouraged many pisciculturists from continuing to breed the *fontinalis*.

Another circumstance must be mentioned which makes the cultivation of the brook char in the second year very unprofitable, namely, degeneration of the eggs caused by overfeeding. That the brood product of such fish as are artificially fed is entirely worthless would be a lesser evil were it not also that the fish themselves perish in great numbers at the spawning time through over-fattening of the internal organs. It is chiefly the spawners that die, as they can not deposit their spawn, which is not thoroughly and normally matured. The char, moreover, requires special qualities and temperature of water. It only thrives in hard, clear spring water of even temperature ranging from 42° to 54° F. The risk connected with its fattening rapidly increases with rising temperature of water, whilst if this is much below the above-mentioned degrees the food taken no longer affords proper nourishment. It has often been proposed to rear the char in running water, but to this the objection must be made that the char would immediately become too formidable a competitor of our brook trout with

regard to feeding, and in all likelihood there is hardly a pisciculturist who would be prepared to substitute the brook char, which can not be disposed of so easily here, for the popular brook trout. For these reasons the breeding of the brook char has been generally neglected in Austria for the last few years, and in some fisheries has even been abandoned altogether.

A promising future appears to lie before the *purpurata*. In growth it develops as rapidly as the *irideus* and it thrives under the same conditions. Its brilliant exterior and slender body, similar to that of the brook trout, are advantages which must not be underestimated. So far, however, the *purpurata* is bred in Austria only in isolated fisheries, and it would be premature to-day to pronounce a definitive decision regarding the value of this beautiful fish to breeders.

The American black bass, *Micropterus salmoides*, is being bred in several pond fisheries side by side with carp. The conditions of growth are favorable. The objections raised against this fish are that it is a great truant and extremely sensitive to the effects of muddy water, which latter occasions great losses in the clearing out of ponds. There is also no great demand for the fish, though it is fleshy and palatable, for the public show a certain aversion to the disproportionate size of the head, which, in fact, equals a quarter of the weight of the whole fish. As the fish is tenacious of life, however, can be easily transported, and is not very dainty in feeding, it may be that in time it will become more popular, especially if breeders succeed in producing it with a smaller head. In the tributaries of the Danube and in pools and stagnant water it could not exist at all.

The tiny California sheatfish is not yet well known in Austria, and as its many good qualities are much underestimated it is not very popular. It is a harmless fish, extremely tenacious of life, and, like the black bass, is often bred in carp ponds. As it is a decided mud fish, attempts have been made to introduce it in waters in which our finer fish have been destroyed through the discharge of factory refuse, river regulating works, and exploitation of water power. The tiny sheatfish has fulfilled all the hopes placed in it and thrives splendidly even in strongly polluted waters. Though it offers only an inferior substitute for our better kinds of fish, it may yet perhaps be destined to play an important part in Austrian pisciculture.

From all this it follows that our most precious acquisition from America is the rainbow trout, as we do not yet sufficiently know the *purpurata*, provided that we shall be able to renew the breed by the speedy importation of eggs from America, and in this conviction we heartily join the Austrian pisciculturist who writes at the close of his observations, "May our friends in America add a new gift to that which they have made us already in the *irideus*, and give us a little from their superabundance. The fish breeders of Austria would be very grateful to them."

CAUSES OF DEGENERATION OF AMERICAN TROUTS IN AUSTRIA

By Johann Franke

Director of the Fish-Culture Establishment at Studenec and Secretary of the Fishery Committee for the District of Krain

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By JOHANN FRANKE,

Director of the Fish-Culture Establishment at Studenec and Secretary of the Fishery Commission for the Province of Krain.

[Translated from the German.]

I have had to do with the feeding of rainbow and brook trout in ponds and inclosures for seventeen years. I have had experience with rainbow trout in clear running water for thirteen years, and much more thoroughly and in detail with brook trout for eight years.

The two species are excellent as breeders, first class and far superior to the native trout (*Salmo fario*). They can consume an astonishing amount of food, their appetite is extraordinarily persistent, and they repay the voracious feeding by astoundingly rapid growth; they remain well, keep their beautiful vivid coloring, and yield excellent spawn, even "red eggs" when in the proper condition and in surroundings suitable to salmonoids. The view that the degeneration of this fish, wherever it has occurred, is a result of natural tendencies and the qualities of our water, and that the degeneration was to be expected in the nature of things, I entirely repudiate, for I am convinced that the degeneration is the effect of artificial conditions unsuitable to salmonoids.

The true reason for the degeneration of these fishes is in faulty methods on the part of the fish culturists. The brook trout especially has been greatly discredited in Vienna and in other places, being pronounced very weak, its flesh distasteful, etc. This may have been true, as it is being bred in a most irresponsible way, the fish being given all kinds of impossible food in order to produce it quickly and cheaply. There is great competition in the sale of spawn, small producers selling not directly to the users but to agents who advertise not only hundreds of thousands but even a million or two as being their own product. The producer does not obtain even 3 crowns (60 cents) per thousand in many cases. Much of this has already been published in German special papers

discussing the subject of degeneration, and many astonishing facts have been brought out. Good eggs are cheap even at 5 crowns (or $1), and a breeding establishment can be maintained properly and on a businesslike footing only when the eggs bring 10 crowns. At present the fishes are bred down into a wretched condition. The much desired eggs from America will degenerate in the same way if the method of breeding for reproduction is not henceforth different from that which has prevailed.

The unfavorable conditions surrounding the American trouts in this country, brought to my knowledge through experience during the long period I have mentioned, I have found to be due partly to inadequate insight into many essentials of fish culture, and partly also to things which could not be changed. I have been able, however, to acquaint myself with some of the phenomena of degeneration and their causes, and some of them I have successfully combated.

I consider the principal causes of degeneration to be:

1. Unhealthy pond bottom, i. e., bottom on which ooze and remnants of food as well as excretions accumulate for months at a time. The slower the current and the longer required for the water to run off, the more dangerous grow the conditions even at a low temperature of from 10° to 13° centigrade. The planting of water cress on the bottom and the introduction of carps and perches is not sufficient by any means, as these fish do not wallow in the ooze at temperatures of 10° to 13°. For example: A spring pond having an area of 140 square meters and a depth of from 60 to 100 centimeters was stocked about the end of August with 1,500 rainbow trout of the same year, and disease appeared in January, 1897; it was impossible to drain the basin without lowering the level of the water in the principal pond and disturbing the entire establishment. The ooze was taken out by means of a strong pump and a rubber hose; in some places it was black and bad smelling. The disease disappeared entirely a few days later. After this I succeeded in saving the one-year-old fishes in low-water ponds with weak currents by means of frequent pumping out of the ooze and by keeping the bottom clean.

2. Substitutes for the natural food. Fresh flesh of fishes (I had only fresh-water fishes) must be considered as natural by the effect produced, even if it is cooked. I never succeeded in keeping the trout healthy for a long period when using substitutes (a mixture of fresh blood cooked with shrimp meal, or the spawn of sea fishes, or fish meal—Ideal brand—and flour as a binding material) without an abundant addition of fresh fish. Within two and at the latest within three months there were traces of change of color to a darker, dimmer hue with a bluish tinge, more noticeable in the many-colored brook than in the darker rainbow trout. If they reached the blackish-hue stage they could not be saved. In such cases live natural food without any adulteration proved the best of remedies.

Latest example from the current year: Spring pond of 90 square meters, good depth, and slow current of the water at a temperature of 10° C.; there were in the middle of February 400 beautiful rainbows from a lot of the previous year, of which 950 had been taken out in apprehension of lack of water in winter and sent to other places in November. The suspicious looking bluish tinge was already awakening our anxiety; there was danger in delay, but the best remedy was natural food. A broad flat pool with spring water flowing through it, all covered with vegetation and algæ, had become free of ice. Here were caught by means of a fine dip net a mass of various small animal life, small and large larvæ of mosquitoes, crawfish, woodlice, small fishes, and even bullheads. The small animal forms came slowly to the surface from the thick forest of vegetation and dirt and were caught up. The entire mixture was then taken to the shallow water near the bank of the pond, where the trout themselves took the food out of this mixture. The pool supplied ample food year after year, thus saving the fishes more than once, though diminishing in abundance each year toward the month of May. Seven of these rainbows died, but all the remaining seemed well and acquired within three months their normal aspect, which they kept. To be sure, they were given no more food substitutes. The last 75 fishes were sent away in July; they weighed each 13 kilograms and stood very well the transportation of 6½ hours, as did also those which were sent away earlier.

As long as the materials for the diet of the small fry and young fishes contained crustaceans and fresh fish, the breeding and rearing went on exceedingly well, but in winter, with the forced use of substitutes, or in proportion to the lack of fresh fishes, the trouble began.

3. Insufficient flow of water through the ponds. The two large ponds have an old accumulation of ooze at the bottom some 20 to 100 centimeters deep; can be emptied only down to five-sixths of their contents at best, as the entire system of springs of the establishment flows through these. This, which it is impossible to correct, is surely an evil, but it had no apparent bad effect upon the larger salmonoids and the breeding fishes so long as the flow was abundant. When the supply grew less, in 1897–98, there appeared again the exophthalmia and the "staggers" now and then. With the decrease of springs these phenomena grew more frequent, several of the native trout (*fario*) became miserably thin, and several rainbow trout yielded spawn that could not be used. In 1904 the establishment went through two or three months without the flow of the springs, and in summer the surface water of the principal ponds at a certain distance from the inflow of the water had a temperature of 18° and near the exit a temperature of 21.2° C. At that time the water was calm, for what current could be expected from a couple of second liters in an area of 1¾ hectares? The water near the bottom was cooler by some 2° to 4°, and the trout lay there

in lethargy and without appetite; only the roaches and a few carp swam slowly about. Good spawn was obtained only in ponds where there was an outflow of springs; there were but few brood fish in the places where formerly could be found some 100 kilograms; and good roe fishes were in still smaller number. In addition to this symptom of degeneration there were others in an increased degree. Anæmia, however, did not appear in the rainbow or brook trout.

No food substitute whatever was given to the fish in the principal pond, in order to forestall a beginning of degeneration. This, however, was without avail. The regulation of the course of the principal river of the country gradually drained away the living water supply of the establishment; the springs coming from the great subterranean stream of the Laibach field went dry, and we were forced to abandon the locality in July of this year.

It is impossible to demonstrate in a more striking way than this the necessity of a good flow of water, *one* of the three conditions—infected bottom of ponds, continuous use of substitute foods, and insufficient flow of water—which brings about phenomena of degeneration, the more rapidly and in so much the higher degree if two or all three causes are operating at the same time.

And what about native trout? I would ask only when and where has there been observed in this fish any greater power of resistance against the abovementioned causes of degeneration? It is not less sensitive than the brook trout and considerably more so than the rainbow.

As to the American trouts in running streams I know of only one drawback to the rainbow, namely, that there is no reason to suppose that it will remain and make a constant abode in particular waters, or that it will immediately leave the abode of its youth; water seemingly of the same character was in reality quite different. In two cases the fry developed in four years into mature fishes. The lingering of the rainbow in certain waters has astonished us as often as its disappearance from the same localities.

The brook trout shows more tendency to remain. In waters where food is abundant this fish surpasses even the rainbow in rapid growth. Contrary to the general opinion that it must have cool water, I saw this fish thrive one summer in water having a temperature of 18° to 20° C. In small creeks, poor in food, it scarcely thrives as well as the native *fario*. In the Stara Voda, which stream I had under my control from 1901 to 1908, it grew to be the principal fish after the first introduction as small fry, while only a few of the rainbow trout had remained there. The native *fario*, which was already there and did well, remained far behind the *fontinalis* in numbers and in rapidity of growth. Only during the last two years, when the stream suffered, like the establishment

of Studenec, from lack of water and of current, the *fario* stood it better than the *fontinalis* and appeared in greater numbers than the latter.

Up to the time when I began to control this stream I knew nothing about the possibilities of the brook trout. Introduced into the stream in March, 1901, as small fry which had not yet been fed, several fishes were caught by me in August weighing from 0.3 to 0.5 kilogram, while the largest weighed 0.65 kilogram; they were fat and round, beautifully tinted, and their flesh was exquisite. The spawn (spawning season from November 7 to December 15) proved good in the hatchery, although the eggs were smaller than those of older fishes. Three-year-old fishes weighed 0.75 kilogram. I never dared to let them grow older through fear of their being stolen.

My regret over the drainage of this stream is greater than for the ruin of the fish-culture establishment.

NEW AND IMPROVED DEVICES FOR FISH CULTURISTS

By Alfred E. Fuller

U. S. Fisheries Station, Northville, Mich.

Models presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

CONTENTS.

	Page.
1. Artificial bass nest	993
2. Bass fry retaining screen and trap	994
3. Collecting tub	995
4. Fish retainer	996
5. Fish attendant's outfit	996
6. Seine for collecting fingerling bass	997
7. Shipping case for fish eggs	998

NEW AND IMPROVED DEVICES FOR FISH CULTURISTS.

By ALFRED E. FULLER,
U. S. Fisheries Station, Northville, Mich.

ARTIFICIAL BASS NEST.

[Exhibit 1. Fig. 1, pl. CIV.]

This form of bass nest, like others in use, consists primarily of a container for the gravel, constituting the nest proper, and a shield to furnish the seclusion required by the nesting fish. Both container and shield, however, are of distinctive design, and the shield, which is detachable, is provided with a waterproof record holder and indicator projecting above the water.

The nest proper is an iron hoop 2 feet in diameter, made of 1½-inch by ⅛-inch band iron. This hoop, placed in the pond and filled with gravel, holds the latter within its circumference without the necessity of any bottom and may be left in position permanently. Riveted at each of 3 quartering points on the outside of the hoop is an iron socket or slot, of size to accommodate a standard 1 inch wide and ⅛ inch thick. By means of these slots the removable shield is adjusted to the hoop.

The shield, 2 feet high and semicircular to fit one side of the hoop, is made of ordinary galvanized sheet iron riveted to three iron standards. The standards, which are 1 inch wide by ⅛ inch thick, extend 2 inches below the sheet of iron they support, and are pointed at the lower end for ready adjustment to the sockets in the hoop. The two end standards are 26 inches in height and flush with the top edge of the shield. The middle standard is higher, projecting above the shield to hold the indicator and record case. The height of the projection is determined by the depth of the water in which the nest is used, the indicator to be always visible above the surface of the pond. The shield and container are coated with paint.

The record holder consists of a waterproof case to contain cards or small sheets of paper and has a number and an indicator on its face. The case is made of 2 rectangular pieces of thin sheet metal, preferably copper, 2½ by 5 inches, with rolled edges to permit one side of the case to slide upon the other. Into the back are slipped the cards or sheets of paper containing detailed

records of the nest. The nest number is stamped or painted on the upper half of the face of the case; in the lower half is fixed a metal pointer, in a dial upon which appear symbols which will indicate to the fish culturist whether the nest is "cleaned up" or contains eggs or fry. A metal pocket is soldered upon the back of the case, by means of which to fit it to the tall standard of the shield.

The especial advantages of this nest are as follows:

1. The shield can be removed to permit placing the retaining screen around the nest without roiling the water or disturbing the nest proper, thereby avoiding injury to the fry by the rolling of the gravel.

2. The nest proper, remaining permanently in the pond, is always in readiness for use without the expenditure of labor to renew each year, and when once installed requires only attaching of the shield, which can be done in the space of a moment.

3. The nest, being of heavy metal, will remain stationary in the pond without being weighted down to prevent floating.

4. A separate and complete record of each nest can be kept as its product advances to different stages, while its condition can be determined from the shore at a glance without disturbing the fish by entering the water or going to the nest in a boat.

5. Nest and shield are easily stored. Fifty of the shields require a space but 2 feet wide, 2 feet high, and 26 inches long.

BASS FRY RETAINING SCREEN AND TRAP.

[Exhibit 2. Fig. 2, pl. CIV.]

The retaining screen and trap exhibited is intended for use in connection with the bass nest just described. It combines with the ordinary cylindrical retainer a device by means of which the fry are entrapped and may be readily lifted from the nest. Certain improvements in the construction of the retainer are also important features.

The retaining screen is made of a piece of 14-mesh galvanized wire cloth 3 feet in width, stretched around a frame consisting of two iron hoops and 4 iron standards. The hoops are made of ⅛ by 1 inch iron bands and are 3 feet in diameter; the standards are 3 feet high. The joinings are everywhere made with stove bolts, which also secure the wire cloth to the frame. At the seam the wire cloth is lapped directly over one standard and an extra upright 3½ feet long is bolted over the lap. The circular inclosure thus built is readily "knockdown" for storage purposes. Upon the projecting upright is fitted the record holder, which was attached to the nest shield described in exhibit 1 and is now to be transferred to carry on the record for the fry. All metallic parts are painted.

The trap is within the retainer. It consists of a hoop fitted over the bottom hoop of the retainer and securing about its circumference a piece of bobbinet

so shaped and seamed as to form a blunt cone about 2 feet high when held in place within the wire-cloth screen. The top of this cone is open, the bobbinet here fitted and secured to an iron ring 4 inches in diameter. To hold the cone in position, two cords attached on opposite sides of the opening are carried to the upper rim of the retainer and there fastened by means of bent-wire hooks at the ends of the cords.

As the bass fry ascend from the nest their natural tendency is to follow the inside of the cone upward to the 4-inch opening, through which they pass to the upper section of the retaining screen. After they have all ascended, this opening is closed with a tight-fitting cap made of a circular piece of bobbinet held in at the edge by an elastic gathering string. The fish are then in captivity. To remove them from the pond, the apparatus is lifted to the surface of the water, the cords holding the cone are released, and the cone telescopes, forming a scaff net, which is then detached from the bottom hoop of the retainer, placed over the collecting tub, and the fish liberated therein.

The advantages of this combined retaining screen and trap are as follows:

1. All the fry that are able to rise from the nest can be captured.

2. They can be taken from the trap at any time desired without regard to roiliness of the water or low temperature.

3. The device is useful in the capture of bass fry in inland lakes which have become overstocked and from which it is desirable to transfer the fish to barren waters or waters more accessible to sportsmen

COLLECTING TUB.

[Exhibit 3. Fig. 3, pl. CIV.]

This tub is convenient for use in connection with the trap described in exhibit 2. It is constructed of ordinary galvanized iron, is 3 feet in diameter, 14 inches deep, and has a 2-inch flaring rim with outer circumference to fit the hoop of the cone-shaped trap. At each of two opposite points in the side is inserted a piece of perforated tin, 7 by 10 inches, extending to within 4 inches of the bottom. Two handles are attached below the rim on the sides transverse to the perforated inserts, and the tub is painted inside and out.

When in use the tub is placed in a wood float 4 feet square, which permits it to be easily towed from nest to nest as the collections are made. In emptying the tub its contents are poured out over the solid side rather than the perforated.

This tub has the advantage of allowing the fish a free circulation of fresh water during the process of collecting, a condition very essential during warm weather. Necessity for changing the water is thus obviated, and handling of the fish, which should always be avoided as much as possible during warm weather, is minimized.

FISH RETAINER.

[Exhibit 4. Fig. 4, pl. cv.]

This article is a convenient means of temporarily confining fish awaiting shipment. It is made of ordinary galvanized iron, and is in effect a taller and slenderer form of the collecting tub described in exhibit 3, with the addition of a combined cover and bail. It is 10 inches in diameter and 20 inches high, with a 2-inch flaring rim and with two perforated strips of tin inserted opposite each other in the sides. The perforated inserts are 6 inches wide by 14 inches in height, reaching from the lower edge of the rim to within 4 inches of the bottom of the receptacle. A stiff wire bail, to which the cover is fastened, is attached on the perforated sides, and the receptacle is painted.

When in use this retainer is set in a wooden float to prevent its sinking. Such floats may be constructed any length, to accommodate any number of retainers, but sections 26 inches wide and 7 feet long, which will accommodate 10 retainers, are found to be most convenient. The apparatus is placed in fresh or running water, and the fish to be carried in one transportation can are placed in one retainer. In emptying the retainer its contents should be poured out over the solid sides instead of the perforated, to prevent injury to the fish.

This device has the advantage of allowing shipments of fish to be prepared in advance of the time of departure, as a free circulation of water is permitted at all times and the fish can be held any reasonable number of days. It obviates extra handling of the fish, which is to be avoided as much as possible, and also enables one man to prepare the shipment without assistance, which is of great convenience for night departures.

FISH ATTENDANT'S OUTFIT.

[Exhibit 5. Fig. 5, pl. cv.]

This outfit comprises an aerating device and a combination ice pick and net, for use in the transportation of fish. The aerator consists of a cylindrical screen made of perforated zinc or tin, and a perforated funnel-shaped plunger with long handle. The screen is 6½ inches in diameter, 21 inches high, with a 2-inch slightly flaring collar at the top, has a perforated bottom, and is fitted with a wire bail. Two heavy wires, crossing each other at right angles, are soldered 2 inches from the bottom to prevent the plunger from striking the latter. The slender dimensions of the screen permit it to be inserted into the ordinary transportation can.

The plunger may be made of an ordinary tin funnel of 6 inches mouth diameter, a shallow tin pan of the same diameter, and a ¼-inch rod bent to form a loop at one end. The funnel is perforated with nail holes, as is also the bottom of the pan, and the latter, inverted, is soldered over the mouth of the

funnel. The rod is inserted into the tube of the funnel, giving the plunger a total length of 18 inches.

To operate the aerator, the plunger is churned up and down in the screen. The screen filled with ice may be used also in cooling the water in which the fish are held.

Both as aerator and cooler this device is especially useful in transporting fry which are the more susceptible to injury in handling, such as shad, pike perch, and whitefish. With these means, moreover, the attendant can give proper attention to a large number of fish in a short space of time and with a minimum amount of labor.

The combined net and ice pick consists of a semicircular frame of 10 inches long dimension, made of no. 6 wire and covered with soft net of any desired mesh. This is fitted into a wooden handle, the opposite end of which holds a disappearing point 3 inches long, made of ¼-inch spring steel.

The net is of use in pouring water from transportation cans in order to replenish with a fresh supply, or for purposes of "doubling up" the contents of two cans, as may be necessary just before delivering from the train. It also takes the place of the siphon and scaff net usually carried by attendants in charge of shipments of fish, and since these and the ice pick are usually carried separately, the combination device reduces the number of articles from 3 to 1.

SEINE FOR COLLECTING FINGERLING BASS.

[Exhibit 6. Fig. 6, pl. CVI.]

This seine, made of heavy bobbinet, is rigged upon two handles consisting of bamboo poles 14 feet in length. The web is 16 feet long and 4 feet wide, corked and leaded, and is attached at each end to a 4-foot steel brail ¼ inch in diameter. The brails are fastened to the bamboo handles by strap-iron hinges, which allow the brails to break but one way. A heavy cord attached to the lower end of each brail passes through a screw eye in the handle at a point the brail's length distant from the hinge. In operation the seine is projected over the water with the brails extended, the back of the hinges downward. The handles are then given a half turn, allowing the brails to drop at the hinges, beyond the school of fish. The seine falls into the water and as soon as the leads touch the bottom of the pond the cords are tightened. Pulling from the lower end of the brails with the hinges bent, the cords draw upon the bottom of the seine, and it is easily hauled ashore.

The use of this seine, since it can be operated from shore, avoids the roiling of the water which occurs when the operators wade into the pond, and it makes possible the capture of fish at any desired time without drawing off the water. The seine is of advantage, among other purposes, in thinning out the fish from time to time to avoid exhaustion of the food supply and consequent cannibalism.

SHIPPING CASE FOR FISH EGGS.

[Exhibit 7. Fig. 7, pl. CVI.]

This case is designed for shipping fish eggs either to foreign countries or points at any distance throughout the United States. It can be constructed of any sound lumber ⅞ inch thick. The outer case is 2 feet wide, 2 feet high, and 3 feet long, with corners halved together to permit of nailing both sides and ends. Its sides are lined with asbestos packing paper, and the bottom with rubberoid roofing paper. The inner case is made of any light ½-inch lumber and is 19 inches high, 20 inches wide, and 32 inches long. The bottom is made of ordinary galvanized iron and has a slope of 2 inches toward the center to a waste pipe. The outside of this inner case is covered with rubberoid roofing paper.

Cleats in the ends in the bottom of the outer case support the inner one and make an air space below it, at the same time raising it so that it projects 1½ inches above the upper edge of the outer case. Between the walls of the outer and inner cases is a 1-inch air space, and this is closed at the top by means of a strip of lumber 2 inches wide inserted edgewise and flush with the inner wall, making the space airtight. This projection fits into the top of the case when the latter is closed.

The inside case is divided into five compartments, one at each end and in the middle for ice, the two others for trays, the partitions all flush with the inner case. The ice compartments are 3 inches wide and of the full width and depth of the inner case. The middle compartment is removable. The partitions are made of ½-inch mesh galvanized-wire cloth and are held in place with 1-inch cleats nailed upright to the sides of the inner case. These cleats also hold the tray stacks in vertical position, and the space they make allows for air circulation and the dripping of the ice hoppers which are to be placed above. It also allows easy access to the trays and permits of inspecting them at all times without disturbing the ice.

The case holds 24 trays for eggs, 12 in each compartment. The trays are made of ½-inch lumber and are 8½ inches wide, 18½ inches long, and 1 inch deep. The bottoms are of fine-mesh wire cloth. Each side of each tray is perforated with five equally spaced ½-inch holes to allow air circulation.

Over each tray stack, resting upon the ends of the vertical cleats, is an ice hopper 10½ inches wide, 18½ inches long, and 2 inches deep, made of ordinary galvanized-iron bottom and sides, with wooden ends. The bottoms of the hoppers are perforated near the sides with ½-inch holes to allow the water to escape. Over the lower end of the waste pipe to prevent the cool air from escaping is a bowl-shaped cap which is always filled with water.

The top of the case, which is hinged, fits tightly over the rabbet formed by the projecting edge of the inner wall, making an air-tight chest. It is provided

with two hasps in front, and is lined with a single sheet of asbestos, a layer of ½-inch lumber, and over these a covering of rubberoid roofing.

The empty case weighs 88 pounds. The space devoted to ice will hold 60 pounds. Allowing 20 pounds for eggs and moss, the whole shipping weight would be 168 pounds. The case is designed to hold about 80,000 steelhead trout eggs, 120,000 lake trout eggs, 250,000 brook trout eggs, or 1,000,000 whitefish eggs.

This case has the advantage of allowing easy access to the eggs for inspection at any point en route. It permits of free circulation of air, thereby producing an even moisture and even temperature for all of the trays. For local shipments or field work the stacks of small trays, ice hoppers, and central ice compartment may be removed and large trays substituted, making a combination case, and avoiding the necessity for three separate styles, as usually required for different distances. The present case has also the advantage of carrying a maximum number of eggs at a minimum weight.

Coating the case inside with paraffin wax will prevent odors, or moisture from swelling the box.

The following tables record a 36-day test given a roughly constructed case of this type, beginning January 29 and ending March 5, 1906. During the first 26 days the case contained 53,000 eyed lake trout eggs. It was not filled, only 10 of the 24 trays being used. Nine of them contained 5,000 eggs each and one had 8,000.

RECORD OF FIRST 26 DAYS OF TEST.

Test day.	Temperature of room.	Temperature on egg trays.	Ice used.	Test day.	Temperature of room.	Temperature on egg trays.	Ice used.
	°F.	°F.	Pounds.		°F.	°F.	Pounds.
1	75	34	80	15	90	35½	25
2	64	34		16	84	35	20
3	82	35		17	85	35½	20
4	71	36	30	18	90	36	20
5	76	34½		19	87	36	20
6	70	35		20	80	36	20
7	60	35		21	81	36	20
8	69	37	76	22	80	36	20
9	74	34½		23	70	36	20
10	85	35	20	24	82	36	20
11	85	36		25	84	36	20
12	82	39	48	26	85	35½	
13	85	35½	16				
14	84	35	20	Total			515

The eggs were looked over on the seventh day and 44 dead eggs were removed; on the sixteenth day 121 dead eggs were removed; on the twenty-sixth day 168.

On the sixteenth day the moss placed over the eggs was removed, the water squeezed out, and the moss then replaced.

The above test was made in the boiler room, and on the ninth day the case was moved nearer the boiler, which accounts for the rise in outside temperature.

On the twenty-seventh day the eggs were all removed from the case, the latter thoroughly cleaned, and the tray containing 8,000 eggs was replaced for a further test of ten days. During the first five of these days the case was outside in a temperature ranging from 14° to 50° F., the last five it was inside the hatching room at a temperature of 50° F.

RECORD OF LAST 10 DAYS OF TEST.

Test day.	Air temperature.		Egg temperature, noon.	Test day.	Air temperature.		Egg temperature, noon.
	Noon.	Midnight.			Noon.	Midnight.	
	°F.	°F.	°F.		°F.	°F.	°F.
27	50	43	34	32	50	50	33
28	35	31	34	33	50	50	34
29	34	19	34	34	50	50	35
30	23	14	33	35	50	50	35
31	30	25	32	36	50	50	36

These eggs were then removed to Clark hatching troughs and at the end of one week hatched, producing good strong healthy fry. The fry were held until the sac was nearly absorbed, and then planted.

The tray containing the 8,000 eggs stood the test for the entire thirty-six days, and at this rate would give the capacity of the case as 192,000 lake trout eggs, thus demonstrating that a much larger number of eggs than claimed for it can be safely transported in this case should occasion demand. During the above 10-day test but 20 pounds of ice was consumed.

FIG. 1.—Artificial bass nest. FIG. 2.—Bass fry retaining screen and trap
(Photographed from models, which were not built to scale.)

FIG. 3.—Collecting tub, with float. (Photographed from model.)

FIG. 4.—Fish retainer, with float. (Photographed from model.)

FIG. 5.—Fish attendant's outfit—aerator screen, plunger, combined ice pick and scaff net. (Photographed from model.)

FIG. 6.—Seine for collecting fingerling bass.

FIG. 7.—Shipping case for fish eggs. (Photographed from model, which was not built to scale.)

A DEVICE FOR COUNTING YOUNG FISH

By Robert K. Robinson

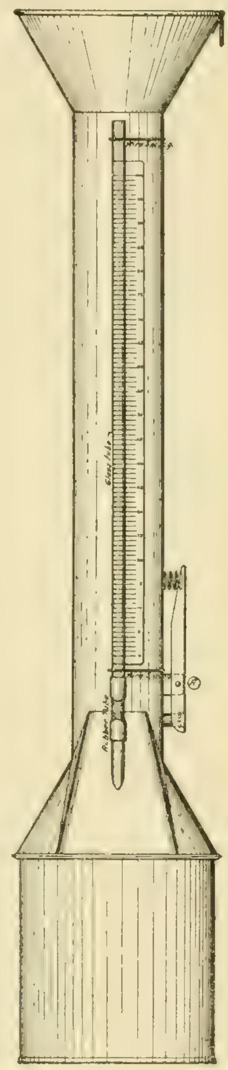
Superintendent U. S. Fisheries Station, White Sulphur Springs, W. Va.

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

A DEVICE FOR COUNTING YOUNG FISH.

By ROBERT K. ROBINSON,
Superintendent U. S. Fisheries Station, White Sulphur Springs, W. Va.

This device is intended as a means of measuring or counting young fish of a size from the fry stage up to the length of 1¼ inches. The instrument is made of thin brass, nickel plated, and weighs about 1 pound. The cylindrical base is 4 inches in diameter and 4 inches high, with a top or neck which tapers to a diameter of 1½ inches, at which point is joined an upright tube of this diameter and 15 inches long. The tube is enlarged at its upper end to form a funnel mouth. Immediately above the base, upon the sloping neck, is fastened a small metal tube, and to this is attached, by means of a short piece of small rubber tubing, a glass tube ⅜ inch in diameter which extends up to the base of the funnel at the top and is held in place by wire clamps. Behind the glass tube, on the main tube of the apparatus, is engraved a 10-inch scale, graduated 10 points to the inch, beginning at zero at the bottom, and each fifth point above numbered consecutively to the top, or to 100 points. The lower end of the small metal tube is set in a shield of metal, which is soldered to the sloping neck of the base of the vessel, this covered area of the latter being perforated to permit the entrance of water into the small tube while screening out the fish. Immediately below the zero point, and to the side of the scale, there is a small vent or valve, which is controlled by a spring lever and serves conveniently to adjust the water level in the apparatus to the zero point on the scale. The mode of using the apparatus may be understood by the following directions:



Measure by means of which to count young fish.

Fill the measure with water until the latter appears in the glass tube slightly above the zero point on the scale. By pressing the upper end of the valve lever the water may be allowed to escape and thus be easily adjusted to the zero point.

Count out from any given lot of fish to be measured 300 to 500 of average size. Put the counted fish into the measure as free of water as possible; this may be done by putting them into a quart graduate and, holding a small hand net tightly over the top of the graduate, draining the water off quickly by inverting the graduate. A perforated dipper may serve in place of the hand net.

The displacement made by the counted fish will be shown by a rise of water in the glass tube above the zero point; then by reading the number of points to which the water rises the average number of fish per point may be easily ascertained. To find the number of fish in an entire given lot, empty the measure, replace the water to the zero point, put the fish in by the operation above described, again read the number of points above zero, then multiply the latter by the number of fish per point, previously ascertained.

The measure should be held perpendicular, which may be accomplished by suspending it between the thumb and index finger placed at the base of the funnel.

A METHOD OF TRANSPORTING LIVE FISHES

By Charles F. Holder

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

A METHOD OF TRANSPORTING LIVE FISHES.

By CHARLES F. HOLDER.

In my somewhat extended experience in handling and transporting live fishes the following has proved the most satisfactory method, as illustrated on a particular occasion:

Large numbers of fish of different kinds were to be collected, upon contract, from fishermen along the Hudson River, from the mouth as far up as Fishkill. My boat, chartered for the purpose, was a water boat, or large tug, with her tanks filled with fresh water and her decks covered with galvanized-iron tanks for salt water. The fishermen came alongside with their fish in live cars, or the tug steamed up to the big nets; cans were sunk beside the cars or the nets, and the fish were transferred without being touched by hand.

A few hours later the tug landed in New York, where big drays, loaded with cans, were in readiness. The insides of the cans were covered with sponges wired into wire fencing and pressed against the interior of the can, the sponges swelling when wet and forming a perfectly soft pad for the fishes. These cans were lowered by a derrick into the tanks of the tug, where men standing in the water transferred the fish to them by means of very wide fine-mesh nets, never touching the fish with their hands. As each can was filled, which was done with great rapidity, it was hoisted to the deck and covered with a tin cap which had an inner false bottom perforated with small holes. With this, at the slightest tip from the horizontal, water flowed into the perforations and dropped back in a shower, thus aerating itself. The moment a dray was loaded it was driven away, not carefully but at a run or fast trot, to the aquarium, the rapid motion being less dangerous to the fish than a long swing.

The original and distinctive features of this method of transporting live fishes are the sponge-lined tanks and the self-aerating device. The latter can not be exclusively depended upon—I found it necessary to make the round of the tanks with a large syringe—but the false lining of the tops reduced the hand labor 50 per cent; and on shipboard, for instance, when the motion is sufficient, it is my belief that fishes might live a week with this automatic aeration of the water in the cans.

I used this method of transporting fishes first in 1876, and on numerous occasions since have found it successful. A chief feature is the care in handling, not a fish being touched by hand, and thus, with the cushioned tanks, not a fish being injured. The sponges also prevent the loss of water.

A METHOD OF MEASURING FISH EGGS

By H. von Bayer, C. E.

Architect and Engineer, United States Bureau of Fisheries

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

A METHOD OF MEASURING FISH EGGS.

By H. VON BAYER, C. E.,

Architect and Engineer, United States Bureau of Fisheries.

In a well-regulated fish hatchery it becomes at times necessary to count the eggs of fishes, so as to know the quantity on hand and prepare for certain shipments of eggs as well as for the future care of the fry. The methods thus

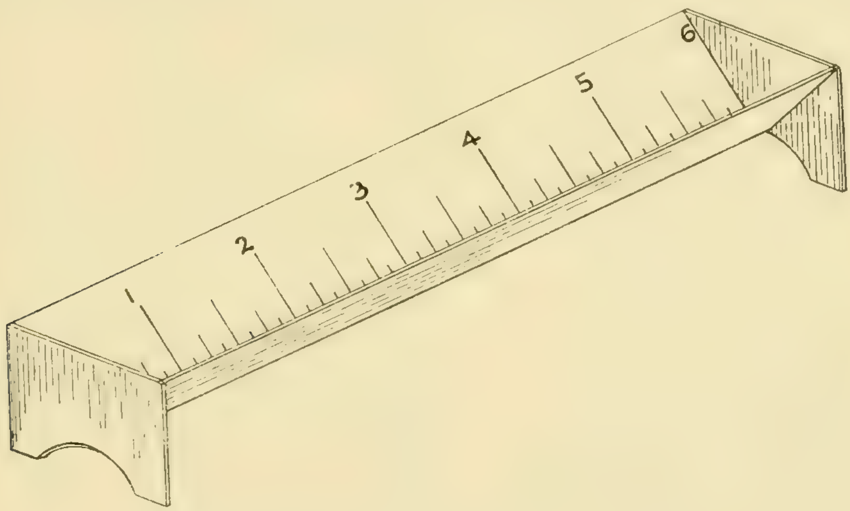


FIG. 1.—Metal trough for use in determining diameter of fish eggs.

far employed have been to determine by actual count the number of eggs contained in one liquid quart measure, and then to multiply said number by the number of quarts of eggs on hand; or to weigh one liquid quart of counted eggs, next to weigh all the eggs on hand, and then by simple proportion to determine the number of all the eggs.

The new method proposed by the writer is first to determine the diameter [a] of one egg, and then to enter with the value of said diameter a table or diagram

[a] By diameter is here understood the diameter of the egg including its surrounding matrix, if any.

in which the corresponding number of eggs per liquid quart or other unit measure is found by inspection.

To determine the diameter of one egg of a certain species of fish, a V-shaped metal trough with scale engraved thereon is used, in which a certain number of eggs is placed one egg deep in a row, the eggs touching each other; the space occupied by the eggs is then read on the scale; this reading, when divided by the number of eggs in the trough, will give the diameter of one egg.

The accompanying table and diagram are self-explaining. They are based on a series of actual counts of eggs contained in a liquid quart measure, these counts fairly agreeing with each other and the theoretical value, and being extended by computation according to the law that solids increase as the third power of their diameters.

Example:

$d = 0.127''$, diameter of whitefish egg (determined).

$n = 33{,}036$, number of whitefish eggs per quart (actually counted).

$d_1 = 0.1406''$, diameter of shad egg (determined).

$n_1 =$ Number of shad eggs per quart (sought).

$$d^3 : d_1^3 = n_1 : n$$

$$\therefore n_1 = \frac{d^3 n}{d_1^3}, \text{ or}$$

$$0.127^3 : 0.1406^3 = n_1 : 33{,}036$$

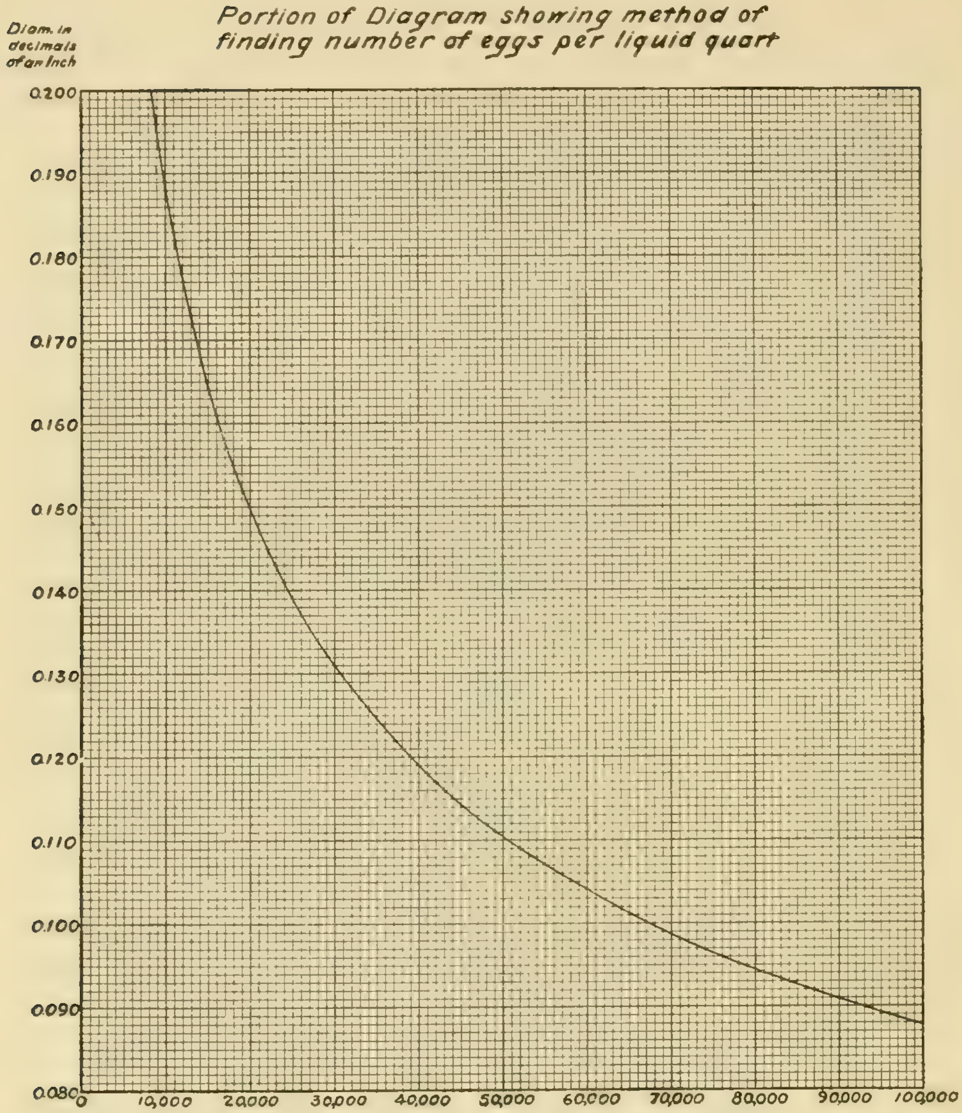
$$n_1 = \frac{0.127^3 \times 33{,}036}{0.1406^3} = 24{,}345, \text{ answer.}$$

TABLE FOR FINDING NUMBER OF FISH EGGS OF GIVEN DIAMETER PER LIQUID QUART.

Diameter.	Number.	Diameter.	Number.	Diameter.	Number.	Diameter.	Number.
Inch.		*Inch.*		*Inch.*		*Inch.*	
0.300	2,506	0.230	5,562	0.160	16,521	0.090	92,826
	2,531		5,635		16,835		95,990
	2,557		5,709		17,157		99,297
	2,583		5,785		17,487		102,762
	2,609		5,862		17,825		106,390
0.295	2,636	0.225	5,941	0.155	18,172	0.085	110,190
	2,663		6,021		18,528		114,172
	2,690		6,102		18,894		118,346
	2,718		6,185		19,270		122,730
	2,746		6,269	0.151	19,655		127,333
0.290	2,775	0.220	6,355	0.150	20,050	0.080	132,170
	2,804		6,442		20,456		137,251
	2,833		6,531		20,874		142,600
	2,863		6,622		21,303		148,220
	2,893		6,715		21,744		154,155
0.285	2,923	0.215	6,809	0.145	22,197	0.075	160,400
	2,954		6,905		22,662		166,995
	2,985		7,002		23,140		173,950
	3,017		7,102		23,633		181,300
	3,050		7,204		24,140		189,070
0.280	3,083	0.210	7,307	0.140	24,661	0.070	197,290
	3,116		7,412		25,197		205,992
	3,150		7,520		25,748		215,204
	3,184		7,629		26,316		224,995
	3,219		7,741		26,901		235,377
0.275	3,254	0.205	7,855	0.135	27,504	0.065	246,410
	3,290		7,971		28,125		258,141
	3,326		8,089		28,764		270,631
	3,363		8,210		29,422		283,936
	3,400	0.201	8,333		30,101		298,132
0.270	3,438	0.200	8,459	0.130	30,801	0.060	313,289
	3,476		8,587		31,523		329,490
	3,515		8,717		32,268		346,828
	3,555		8,851		33,036		365,405
	3,595		8,987		33,829		385,331
0.265	3,636	0.195	9,126	0.125	34,647	0.055	406,733
	3,677		9,268		35,492		429,750
	3,719		9,413		36,364		454,539
	3,762		9,561		37,265		481,270
	3,806		9,712		38,198		510,139
0.260	3,850	0.190	9,866	0.120	39,161	0.050	541,362
	3,895		10,023		40,156		575,173
	3,940		10,184		41,186		611,893
	3,986		10,348		42,251		651,776
	4,033		10,516		43,354		695,223
0.255	4,081	0.185	10,688	0.115	44,494	0.045	742,613
	4,129		10,863		45,676		794,400
	4,178		11,042		46,899		851,128
	4,228		11,225		48,166		913,380
0.251	4,279		11,412		49,480		981,852
0.250	4,331	0.180	11,603	0.110	50,841	0.040	1,057,350
	4,383		11,799		52,254		1,140,780
	4,436		11,999		53,720		1,233,250
	4,490		12,203		55,239		1,335,960
	4,545		12,412		56,817		1,450,406
0.245	4,601	0.175	12,627	0.105	58,456	0.035	1,578,320
	4,658		12,846		60,159		1,721,630
	4,716		13,069		61,925		1,883,020
	4,776		13,298		63,766		2,065,130
	4,835		13,533	0.101	65,680		2,271,500
0.240	4,895	0.170	13,774	0.100	67,670	0.030	2,506,310
	4,956		14,020		69,741		
	5,019		14,272		71,899		
	5,083		14,529		74,146		
	5,148		14,793		76,486		
0.235	5,214	0.165	15,064	0.095	78,927		
	5,281		15,341		81,473		
	5,350		15,625		84,130		
	5,419		15,916		86,904		
	5,490		16,215		89,800		

CONVERSION TABLE.

1 inch	= 25.4 millimeters.	1 liter	= 1.0567 quarts.
1 millimeter	= 0.03937 inch.	1 pound	= 0.4536 kilogram.
1 quart	= 57.75 cubic inches.	1 kilogram	= 2.2046 pounds.
1 quart	= 0.9464 liter.	Fahrenheit	= 9/5 centigrade ± 32°.
1 liter	= 61.0234 cubic inches.	Centigrade	= 5/9 Fahrenheit ± 32°.



Directions: Find the line on the left margin corresponding to the given diameter; follow said line to the right until it intersects the curve; from this intersection proceed at right angles to the lower marginal line of figures and there read the required number of eggs per quart.

If diameter is given in millimeters multiply by 0.03937 to reduce to inches.

AN IMPROVEMENT IN HATCHING AND REARING BOXES; WITH NOTES ON THE CONTINUOUS FEEDING OF THE FRY OF SALMONIDÆ

By G. E. Simms

Ex-Curator of the Brighton Aquarium, Brighton, England

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

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It will, I think, be admitted by even the most conservative exponent of modern pisciculture that there is ample scope for improvement in the type of box now used for hatching and rearing, *inter alia*, the eggs and fry of salmonoids. Speaking broadly, it appears to me that it would be impossible to conceive and, having conceived it, to design an appliance which so thoroughly combines in a small compass the minimum of utility and the maximum of imperfection characterizing the square cornered, oblong pattern of wooden box on which pisciculturists, for lack of a better form of apparatus, are forced to depend for carrying out one of the most important sections of their work. It is not improbable that this may be regarded as a too sweeping indictment of an old and valued servant—if I may be permitted so to describe an inanimate object—but, at the risk of differing from those of my hearers who later on will be my critics, I venture to maintain that, apart from the fact that by its agency fish ova can be brought to maturity, the rectangular wooden hatching box has not a single redeeming quality attached to its name. Indeed, so much so is this the case that I will advance a step further and assert that any utility it may possess in this connection is altogether nullified by the facilities it provides for the unchecked production of fungus, which render it a constant menace and danger to eggs, alevins, and fry alike, so long as they are confined within its sphere of influence.

Three factors are responsible for this unsatisfactory state of affairs. These are the material of which the box is built, its rectangular form, and, last but not least, the position at which the waste-water outlet is situated. A moment's consideration will convince anyone with a practical knowledge of the interior of a hatchery of the correctness of my statement. From either a practical or a

scientific point of view, wooden appliances leave more to be desired than they give. Not only are they heavy, unwieldy, and liable to leakage at odd and inconvenient moments, but they have the additional disadvantage of becoming water sodden and readily receptive to the spores of fungus. With the object of preventing any possibility of attack from this, the pisciculturist's most insidious enemy, the services of the charring iron are brought into requisition to antisepticize the interior of the box by superficial carbonization. A more brilliant method of holding in check an ever-present evil of any kind has seldom or never been devised. The only fault that can be found with it is that when those parts of the box which have undergone carbonization are subjected to the action of water any antiseptic properties they may have possessed while dry rapidly disappear, and in a short time the last state of that box as a fungus-fighting appliance is worse than its first. The mischief does not, however, end here. In the course of a few days the inside of the box up to water level—assuming, of course, that it is in use—becomes covered with a viscid slime, and this, in conjunction with the roughened, semispongy substance of the carbonized wood, forms a secure resting place on which particles of excrement and of unconsumed food, as the case may be, can decompose and generate a more or less plentiful crop of fungus.

Turning to the form of the box, what do we find there? The supply, whether it falls in from above or is so arranged that it enters from below, has to force itself against the whole volume of the contents of the box, and consequently its force is expended and ceases to make itself felt before it has, at the outside, reached more than 3 inches from its point of entry. In other words, it is absorbed into and assimilates with the water into which it is poured instead of forming, as it should, a gentle current running over the eggs from end to end of the box. This raises a question as interesting as it is important scientifically and commercially, viz, are the eggs under conditions such as these, which in no wise conform to natural conditions, properly oxygenated by the water in its upward progress toward the outlet? Furthermore, is the passage of the water from the inlet to the outlet equal or intermittent? In regard to each I hold an opinion which is not an affirmative one, but I leave the definite solution of this very interesting problem to those who have more time and opportunities at their disposal than I have for carrying out the necessary experiments.

No doubt many of you have watched a pair of trout making preparations for spawning, and as you have watched you have wondered at the marvelous instinct which prompts the male fish to select a point above the redd, i. e., the spawning bed, with just sufficient stream to carry the milt as he discharges it in a milky cloud over the eggs which have been deposited by his mate. But the two fish—and to the lady must be accorded her fair share of credit in their

joint undertaking—have a much deeper purpose in view than the efficient impregnation of the eggs alone. Their instinct also teaches them that the eggs, without an adequate supply of oxygen, will not come to unimpaired maturity, but will produce weakly alevins, and that unless a current of water passes over the eggs while incubation is proceeding they will not obtain a requisite amount of oxygen. Here it appears to me that the dumb instinct of the fish is far superior to the reasoning power of man, as exemplified by the latter's idea of a suitable form of box for the artificial hatching of fish eggs. You will therefore see why I asked, a short way back, whether eggs incubated in a rectangular hatching box are properly oxygenated by the water in its upward progress toward the outlet.

On this side of the Atlantic, wherever in the country districts there occur diverging roads, a handing post to indicate the direction and distance of adjacent villages and towns is erected by the local authorities. Among our rural folk, whose sense of humor is not of a wildly extravagant character, it is a standing joke that their spiritual guides are like handing posts because they point the way to all and sundry and never follow it themselves. But the piscicultural writers of my acquaintance can not be held altogether free from something of the same reproach. To a man they impress on their readers the necessity of extreme cleanliness as an absolute essential to success in pisciculture. No one will be inclined to dispute the soundness of this advice until he attempts to put it into application. Then he will be compelled, probably with some reluctance, to confess he has attempted an impossible task. Leaving "extreme" cleanliness out of the question, it will be found that even ordinary cleanliness can not be observed, and for this reason: The rectangular hatching box is, de facto, merely a pocket of water which can admit, but which, owing to the position of the outlet, can not eject, extraneous matter that may enter it. It therefore follows that when the alevins have arrived at the fry stage and require feeding, any particles of food that they happen to miss must in the natural order of things gravitate to the bottom of the box, where they become saturated with water, decompose, and generate fungus. In this connection it must not be forgotten that animal tissue, however carefully it is treated in converting it into fish food, can never lose its identity as animal tissue. Its juices may be dissipated and dried up by the application of heat and its substance by hard pounding reduced to the finest powder, but its tendency to decompose is only dormant and will actively assert itself immediately the powder or any portion of it is brought under the influence of moisture. The filthy and insanitary condition of the interior of a rectangular box after fry have been hand fed in it for a few days can therefore be better imagined than described. My remarks on this head are of course dictated by the assumption that the methods followed by American and English pisciculturists are identical, viz, that the fry are

retained in the hatching boxes and fed until they are ready to be transferred into the rearing ponds.

The shortcomings of the rectangular type of hatching and rearing box have, I regret to say, occupied more space than I originally intended to devote to them. I am, however, assured that the interest and importance of the subject to pisciculturists will be its own apology, if an apology be needed, for the tax I have been compelled to impose on your patience and good nature before dealing with the principles in construction which should be observed in making a hatching and rearing box which will combine thorough efficiency with effective sanitation. These are three in number and are as follows: (1) The material of which the box is constructed must not only be impervious to water, but must have a smooth, hard surface which will act as a preventive against the lodgment of the spores of fungus; (2) the box must be shaped so that the water is kept in constant circulation so long as the supply is running; (3) the outlet must be placed at a point which will enable it to maintain a direct current over the eggs during their period of incubation and at the same time, when the fry have to be fed, act automatically to remove any small particles of unconsumed food.

As regards material, I have met with nothing equal to highly glazed earthenware, and were I in a position which would enable me to indulge in the luxury of an experimental hatchery the whole of its equipment would be of china or delft. These materials are, however, too fragile for the requirements of a hatchery in which from 150,000 to 250,000 eggs are laid down each season, and consequently we shall have to cast about for a material which will make an effective substitute. Thin enameled iron, such as is used in the manufacture of basins, pie dishes, and other domestic utensils, will answer the purpose admirably. To me personally it is a matter of surprise that it has not already been generally adopted for piscicultural work in preference to wood, seeing that of the two materials it is, size for size, relatively the lighter. Moreover, it has the additional advantage of being cheaper, is easier to keep clean, and possesses far greater durability.

Coming to the second principle of construction, I have endeavored to show that any approach to the conditions under which eggs are incubated in a natural state is not attainable with a rectangular hatching box. It will, therefore, be necessary to abolish straight lines in favor of curves, as indicated in the accompanying sketches. Perhaps, however, you may grasp my meaning more readily if, in imagination, you take a length of piping of fairly large dimensions and divide it lengthways into equal halves. At each end of one of these halves affix a circular head and you will then have an exact representation of the type of box I am endeavoring to describe, but as yet minus the outlet. This consists of a circular opening of at least 3 inches in diameter, cut at one end of the box,

its lower edge being exactly flush with the bottom of the box (fig. 1). The orifice to which I refer opens into a pipe which is joined to it and runs upward to within an inch of the top of the box, where it turns outward and acts as a spout (fig. 2). The pipe must be of the same dimensions as the circular orifice. In order to prevent the escape of alevins and fry, the orifice where the pipe is fixed into the box should be covered with a grating of fine parallel wires at spaces of about $\frac{1}{16}$ inch apart. The grating may be a little larger, but must on no account be smaller, than the opening of the pipe on which it rests, or the ring to which the wires are soldered will obstruct the passage of any light particles that are being carried away by the outfall. To support the box two semicircularly cut-out boards, placed on edge, will be required when it is placed in the hatchery. These, I should say, are detachable, the box being held in position by its own weight. Figure 1 will explain the action of the box. It will be seen that the supply falls in at B and, so far as the surface is concerned, follows the course marked by the arrows, while a current extending from B to C is caused by the outfall picking up and ejecting any light particles that happen to gravitate within its influence. It is needless for me to add that the box must be fitted with a cover, so that the eggs may be protected from the effects of the light during their period of incubation.

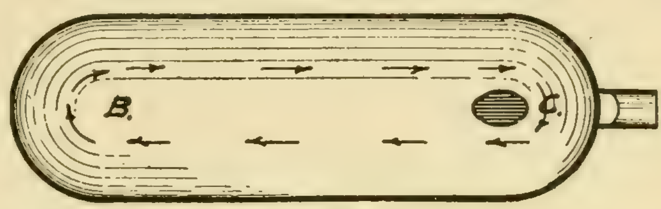

Fig. 1.—Plan.

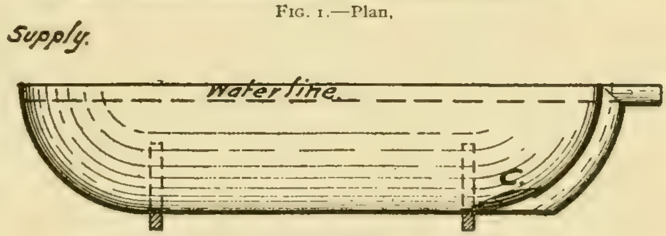

Fig. 2.—Longitudinal section.

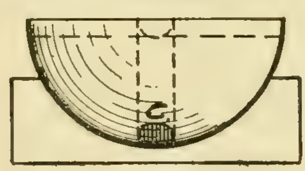
Fig. 3.—Cross section.

DESIGN OF PROPOSED HATCHING AND REARING BOX.

The furnishing of the box with baskets or with grills, as the case may be, is a matter which must be left to the discretion of the pisciculturist who has to use it. If baskets are decided upon they can be fixed in position exactly as they are in the rectangular hatching box. If, on the other hand, grilles are employed, they can be held in a light iron frame resting on a series of studs projecting from the sides of the box. Next season I hope to have one of these boxes fitted with a set of wire baskets, not more than an inch in height and divided by longitudinal slips into compartments which will take five rows of eggs side by side. The

baskets will be shaped to the curve of the walls and will be in contact with the bottom. By this means I think it will be possible for the eggs to receive the full benefit of the current caused by the outlet.

The practice of feeding fry with artificial food while they are in the hatchery appeals to me as being about as obsolete and out of date as the type of box in which they are hatched. Not only does the preparation of the food and its subsequent administration involve time and trouble, but there is attached to it the danger of fungoid outbreaks from the particles which have escaped the notice of the fry and are decomposing on the bottom of the box. It is within the knowledge of every pisciculturist that fish raised from the same batch of eggs and reared under artificial conditions always exhibit a considerable diversity of growth; that is to say, there is an ascending scale of sizes running from what may be described as ordinary fish to medium and large. In a natural state of life, fry can and do feed whenever they are assailed by the pangs of hunger, but in a hatchery they must perforce wait until the time fixed for the attendant to come round and give them their food. My experience teaches me that the divergence in growth to which I have referred is accentuated, if it is not increased, by this intermittent feeding during the fry stage. For some time past I have been using a curious little gregarious worm, the *Tubifex rivulorum*, which is more generally known as the summer worm or mud worm, and I find that it makes a magnificent food for fry from the moment they have absorbed the umbilical sac until they are ready to go into the rearing pond. These little worms are found in masses along the alluvial soil at the edges of ditches and ponds. They vary in length from an inch to 3 inches and resemble in appearance animated threads of floss silk. If the water above them is disturbed they will immediately disappear by withdrawing themselves into their burrows in the soft mud. They soon, however, recover from their fright, come out again, and at once recommence the restless movements with which their numbers and bright color attracted the passer-by. It is the tail end of the animal which is protruded out of the mud. The skin of these worms is so fine and transparent that not only can the blood be seen through it, but under an ordinary magnifying glass the internal arrangements of the creatures may be plainly observed. When taken from the water these worms resemble to the touch a piece of very soft jelly, but their full beauty is not apparent until the lump is placed in a clear glass vessel filled with water, when it assumes the appearance of a magnificent scarlet zoophyte, with a multitude of waving tentacles constantly in motion.

In using these worms for feeding fry all that is necessary is to distribute three or four pieces, about an ounce each in weight, at different parts of the rearing box, and the fry will commence feeding upon them and will require no further attention. Fry so reared make better blood and better bone than those brought up on artificial food in the usual fashion, and, unlike the latter, they

never become tame. They also rise readily to floating particles, and consequently I do not think that the slightest fear need be entertained that the use of these worms as a primary food will train the fry to become ground feeders at a later stage of their existence. *T. rivulorum* is pretty widely distributed throughout England and the continent of Europe, but I have no idea whether it extends to America. In regard to its introduction into the latter country, it is such a fragile, insignificant creature that I do not think it could, under the influence of an altered environment, do the slightest harm; and if any enterprising pisciculturist in the United States wishes to give it a trial I shall be very happy to extend to him any assistance that lies in my power. Given a nice, soft stretch of mud, covered by an inch or so of water, and an equitable climate, the mud worm will flourish apace and multiply with a truly surprising rapidity. It has been tried on trout fry in several of the leading hatcheries in England, and the reports I have received concerning it have been of a most favorable character, the only fault to be found with it being that it is an exceedingly expensive food. As the hatcheries mentioned above have had to purchase their supplies from London at the rate of 3 shillings 6 pence per quart, this complaint is quite justified, but if the pisciculturists who make it will only go to the small amount of trouble necessary for laying out a worm bed, they will find that *T. rivulorum* is a cheap and invaluable food for their fry.

DEVICES FOR USE IN FISH HATCHERIES AND AQUARIA

By Eugene Vincent

Fish Culturist, Aquarium of the Trocadero, Paris

Designs presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

CONTENTS.

	Page.
Artificial pond with siphoid outlet for regulation of height of water	1027
A siphoid outlet for hatching and rearing troughs	1029
A suction apparatus for cleaning hatching and rearing troughs	1030
A cleaning device for ponds or aquaria	1032
Oxygenation and vacuum-producing apparatus	1033
Scraper for preparing fish food	1034

DEVICES FOR USE IN FISH HATCHERIES AND AQUARIA.

By EUGENE VINCENT,
Fish Culturist, Aquarium of the Trocadero, Paris.

[Translated from the French.]

ARTIFICIAL POND WITH SIPHOID OUTLET FOR REGULATION OF HEIGHT OF WATER.

This pond is made of cement, the bottom having a layer 0.05 meter in thickness and a lining of 0.02 meter, the sides being 0.08 meter in thickness. The dimensions are 12 to 15 meters by 3 meters, with any desired depth, and the ends are rounded. Crosswise the bottom slopes from the middle upward at the degree of 0.05 meter per meter, which equals 0.75 meter for a side of 1.50 meter. With this slope the pond may be cleaned by simply sweeping toward the center or by means of a few buckets of water thrown against the sides. It is fed by one or more troughs which empty into it with a stream of 0.20.

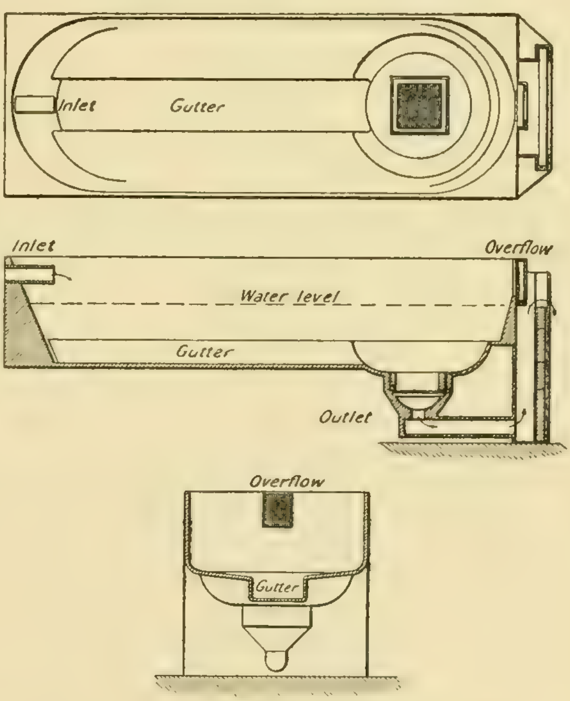

FIG. 1.—Design for artificial pond with siphoid outlet.

The pond must be level in lengthwise direction, in order to preclude danger of leaving any dry area below a given height. In the middle of the bottom of the pond, beginning at the intake end and terminating in a circular basin which occupies the opposite end, is a gutter at least 0.50 meter in width and 0.12 to 0.15 meter in depth. The circular basin is from 1.50 to 1.80 meters in diameter, and 0.20 to 0.30 meter in depth. With the gutter it serves to hold

the fish when the water is drawn out of the rest of the pond for cleaning. The cleaning process itself is simplified, since a man may enter for the purpose and walk about on the bottom of the pond.

So far the pond is not provided with any outlet. In the wall opposite the intake, 0.15 or 0.20 meter above the gutter in the bottom of the pond, is an aperture 0.50 to 0.60 meter square, covered with wire netting. This, however, is not an outlet but an overflow. The outlet proper is in the bottom of the large circular basin and consists first of an opening 0.60 meter square and 0.10 to 0.12 meter deep. Into this square is set a wooden box with a wire mesh bottom, and this box, filled with coarse gravel, rests upon an iron grating 0.60 by 0.60 meter. Below the grating is a circular basin 0.50 meter in diameter and 0.15 meter in depth, with an opening in the center which leads into an outflow pipe.

The outlet provided, the regulation of the water level in the pond remains to be accomplished. This is done by carrying the outflow into a tank or other receptacle outside the pond, in which any desired level may be maintained by regulation of its overflow. The latter is controlled by a board wall or dam constructed of removable sections.

In addition to the convenience of this construction in regulating the height of water in the ponds, there is afforded every protection against loss of the small fish, since the water in leaving must pass through gravel the size of hazel nuts; the cleaning of the pond may be accomplished without injury or shock to the fish; all impurities fall into the gutter and are carried off through the circular basin, while the fish, seeking the incoming current, are in the upper strata of water and away from all such impurities as do not pass through the screened outlet; the fish are provided with desirable currents derived from the action of the siphon, and the pond is continuously self-cleaning. When the fish are larger the gravel may be removed, and still later the screen itself may be discarded.

Fish culturists will appreciate the importance of perfect control of their rearing ponds. A construction such as this described is possible wherever there is a fall of at least 1 meter in the water supply, since it is not necessary to take the siphon apparatus into account. There is but one thing absolutely necessary to provide against—namely, the possibility of emptying the pond entirely, down to the screen with the gravel. It is of little importance that the outflow pipe is not emptied; the water will always flow off, on account of the difference of level.

The design has been adopted with satisfactory results in several fish culture establishments in France.

A SIPHOID OUTLET FOR HATCHING AND REARING TROUGHS.

The various systems of outlet in most fish-cultural equipment are defective in several ways, as I have had occasion to observe on visits to different establishments. The young fish escape in the outflow, perhaps, due to its faulty construction or installation; many of them are caught in the perforations of the sheet-iron cap and die there; many others are killed or injured by the fingers that try to rescue them; overflows are caused by the clogging of the perforations; the water is not thoroughly renewed and the trough becomes infected with germs of disease. All this is too familiar to need to be dwelt upon. I have sought to overcome various difficulties by the following device.

I have provided a large cylindrical wire screen or cage, which is set over the outlet and incloses the outlet apparatus which I shall describe. The large surface of the screen gives free course to the water without attracting the young fish and thus becoming a means of their destruction.

In the daily procedure of changing the water in the rearing troughs, I desire to be able to lower the level to a given point without the necessity of losing time waiting beside the trough. To accomplish this I have made, first, for the orifice in the bottom of the trough, a water-tight collar of two pieces screwed together with a leather washer between. The lower piece is supplied with lugs extending downward, and into this collar is inserted a tube, making an ordinary standpipe. With this form of outlet, however, the water is renewed only at the surface, the bottom water, with remnants of food, refuse substances, etc., being left unchanged. I have accordingly elaborated the standpipe into a form which constitutes an unfailing cleaning device. It carries off all the solid matter

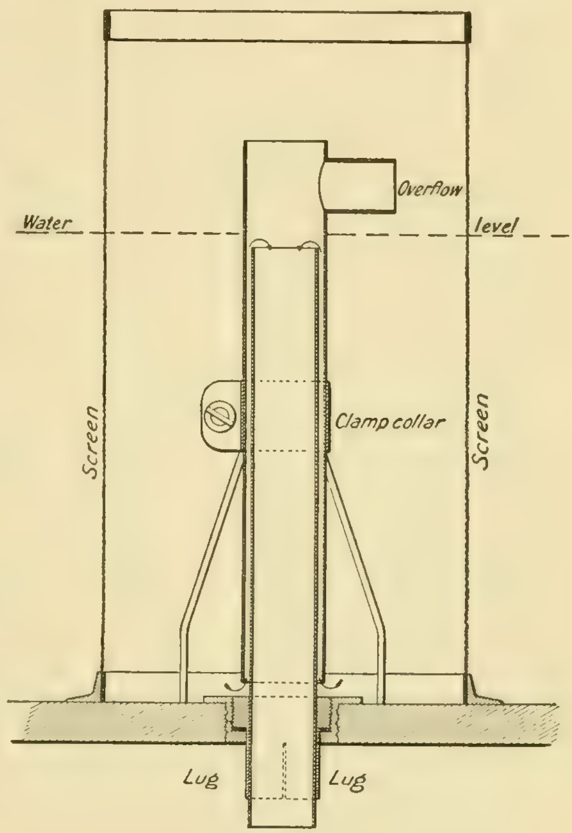

FIG. 2.—A siphoid outlet for hatching and rearing troughs.

that passes through the screen, and affords a desired current for the young fish, which do not like to be inactive.

For this purpose a second slightly larger tube is slipped over the standpipe and, by means of a clamp collar supported on three legs, is held with its lower end just above the bottom. The current thus produced can be regulated, greater force being obtained when desired by lowering the outer tube and thus preventing the full outflow of water. This raises the level in the trough, and the difference between the level in the trough and the stream which can escape—namely, the height of the inner standpipe—makes the pressure to force the water up from the bottom and carry with it the refuse matter in the trough. It is not in a trough such as this that there will be ill-smelling bottom water.

The apparatus does not, as one might think, act merely as do communicating vessels. With a flow of 2 to 3 liters per minute I obtain a difference of level of 3 to 4 centimeters, according to the elevation of the outer tube. By regulation of this tube, which is very simple, both surface and bottom water will be renewed. If only the lower water were emptied an oily layer would form at the surface and act as an insulator between the air and the water.

As the aquarium of the Trocadero is supplied by sluices, in the flow of which there might be the same fluctuations as in the river, I have provided an emergency overflow to balance any sudden rush of water.

When it is desired to remove some of the fish from the trough the whole apparatus may be removed, the mouth of the outlet in the bottom of the trough being closed with an ordinary cap or plug.

A SUCTION APPARATUS FOR CLEANING HATCHING AND REARING TROUGHS.

This device is designed for use in the removal of dead eggs or fry, remnants of food, or any undesirable substance that may be found in the troughs. The use of the usual metal or wooden tweezers, or perhaps long pins, too often causes the eggs to burst, thus spreading infection from their decomposed contents. Little glass pipettes are used, taking one egg at a time. But this often escapes and, falling to the bottom of the trays, is left to give rise to *Saprolegnia*.

To meet these difficulties I have used a pipette with a rubber bulb attached. The tubes vary in diameter, according to the sizes of the different species of eggs, and are 0.25 meter long, being slightly bent at the entrance to the bulb. At the outer end is a ring of blue glass to guide the eye of the operator. With the aid of this form of pipette 15 or 20 eggs may be taken up to be thrown out of the trough at one motion of the operator.

Upon this appliance as a basis I subsequently devised a second means of cleaning by combination with the siphon principle. The later apparatus

consists of a long rubber tube attached, with metal handle and connections, to a blue-tipped pipette on one side and to a rubber bulb on the other. The bulb normally receives its air supply through a small rubber tube which is connected with a metal piston valve inserted in the large tube some 0.60 meter below the bulb. An auxiliary air valve in the handle is controlled by a little piston within reach of the index finger of the right hand.

To use this apparatus have the lower end of the large tube and also the lower piston valve below the water level existing in the trough. Squeeze the bulb with the right hand, press the lower piston with the left, and then, putting the end of the glass tube in the water, release the bulb. Then release the piston and the siphon will have started. The glass tube may be directed at will. If the suction is too strong it may be regulated by the piston in the left hand.

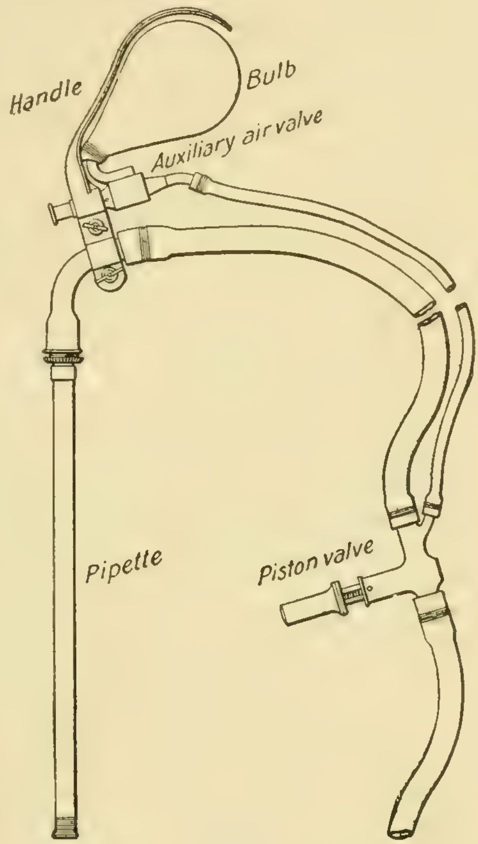

FIG. 3.—Apparatus for cleaning hatching or rearing troughs.

Should a good egg be picked up by mistake it may be readily replaced without waiting for it to discharge at the lower end of the rubber tube. Stop the flow of water by closing the lower piston with the left hand; then press the bulb to expel the air from the small tube upward into the larger, the mouth of the glass tube being meanwhile under water. If this does not force the egg out of the glass tube continue to hold the piston closed, squeeze the bulb with the right hand, and then with the index finger press the little auxiliary piston at the end of the handle. If now the bulb is released it will fill. Removing then the pressure from the little piston on the handle there can be no escape of air at this point when the bulb is compressed, but only backward in the main tube, for the discharge outward is cut off by the closed lower piston valve. The egg will thus be forced out of the glass tube.

Care should be taken to avoid drawing water into the bulb, but in such event a discharge may be effected by proceeding as just described except that the lower piston valve is in this case left open.

This apparatus has proved most successful and obviates the necessity of putting the hands in cold water to do the work of picking the eggs.

A CLEANING DEVICE FOR PONDS OR AQUARIA.

The imperfect construction of some ponds, not permitting them to be entirely emptied, necessitates the use of various means and implements, such as dip nets and even shovels, for cleaning. With even the greatest care it is difficult to maintain the cleanliness necessary to avoid mortality among the fish.

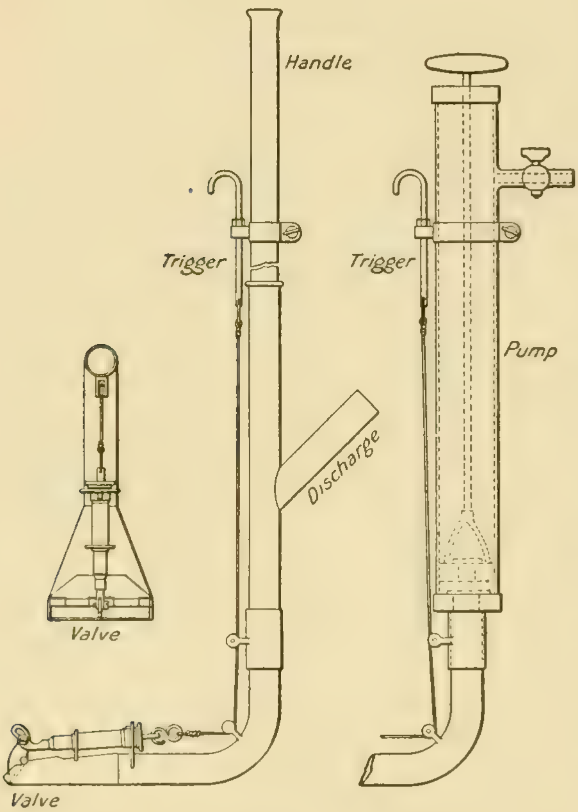

Fig. 4.—Cleaning device for ponds and aquaria.

The present device enables the fish culturist to prevent disease by more thorough cleaning, and also by avoiding the bruises inflicted upon the fish in the course of the ordinary cleaning process if the water is muddy. It also prevents the disagreeable taste of fish reared in muddy and ill-cleaned ponds.

The apparatus is constructed upon the principle of the foregoing rubber siphon and glass tube. Being for larger work, however, it is made of brass pipe with rubber or canvas connections. It consists of a main arm terminating in an elbow joint which is expanded into a flat triangular cavity with an entrance valve. This valve, opening upward, is controlled by a lever attached by a cord to a trigger on the handle of the apparatus. The handle, which is of wood and inserted in the upper end of the main tube, may be of any desired length. Branching off the main tube a short distance below the handle is an arm for connection with the discharge pipe.

In operation the discharge arm may be attached to rubber or canvas hose, with outlet below the level in the pond or tank, and the apparatus guided about over the bottom by means of the handle, the suction being regulated by the cord attached to the valve. In cases where the pond may not be emptied,

and the siphon therefore is not feasible, the handle is removed from the cleaning apparatus and a pump attached. A small suction pump, such as used in gardens, is very suitable. If for any cause convenient, the apparatus may be left in the pond, for with the valve closed the suction can not act.

OXYGENATION AND VACUUM-PRODUCING APPARATUS.

This apparatus is in effect a section which may be introduced into a supply pipe, and consists of an exhaust chamber and an air-supply tube, with the essential feature of a movable jet. The differences of water pressure and sizes of supply pipes render a stationary jet ineffective or even useless at times.

The model here represented has a jet of 5 to 6 millimeters diameter, adjustable by means of a screw on the outside, and sends air into the water to a depth of about 4 meters, from an opening of 20 millimeters. It may be mounted with openings varying from 20 to 26 millimeters. The lower part of the apparatus is provided with a movable tube having a conical entrance, to divide the water better and make the vacuum stronger.

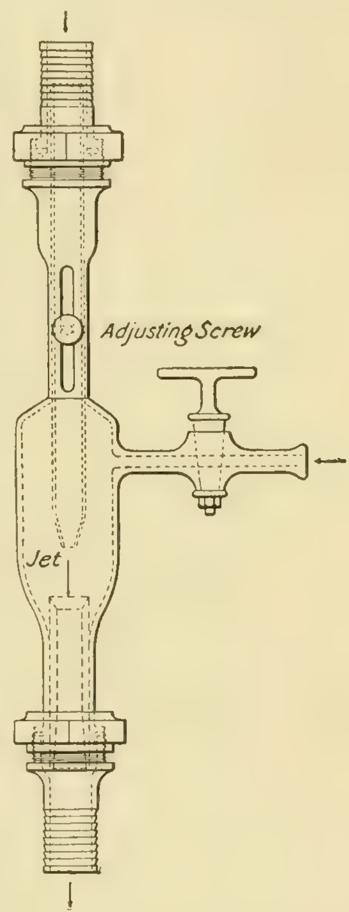

Fig. 5.—Oxygenator and vacuum producer.

The pressure of the water of the Vanne is diminished in the sluices of the Trocadero Aquarium by the many separate outflows, and to provide the desired currents, 13 of these oxygenators have been installed. The fishes playing in the numerous silvery bubbles which rise from the bottom arouse much admiration from the public, and it will be readily believed that the fish are clean and never sluggish. Small or large, they thrive with this kind of aeration, which brings them artificial currents of water which they did not find in these same ponds before. These currents, moreover, do not allow the food given to fall to the bottom when it is sprinkled in. The young fish, some 5 or 6 weeks old, may be seen to catch in passing the small particles of food which the water brings them. The ponds are from 2 to 3 meters deep, from 7 to 8 meters long, and from 2 to 3 meters wide. These oxygenators render great service; it is a hygienic method which ought to be used wherever possible.

This apparatus may be used without disarrangement for the purpose of producing a vacuum in boxes specially prepared for the preservation of food for fishes and even for the shipment of fishes destined for market. It may be

of various sizes and may be placed at the base of a reservoir or even in a receptacle in an automobile for the transportation of fishes alive. In this case the motor will turn a small pump in the apparatus and this even during stops, with the exception of cases when the motor itself does not work.

I have a small oxygenator at the extremity of a small hand pump, to serve me for long transportations. This is more practical than an air pump, the globules from which are too large and must be divided. By means of its water jet, which carries the air along, the oxygenator divides its globules, and these rising less rapidly to the surface, aerate the water much better than the large globules.

The discharge pipe of the oxygenator must be sufficiently large to contain at the same time the air and the water which must pass through it together. Thus if it should be found necessary, as for instance, if the ponds need to be cleaned by flushing, it is possible to attach at the connection of the air pipe a joint identical with the water pipe and use this double water supply in spite of the presence of the oxygenator which might seem to intercept it. Or the spigot of the air pipe may be closed and the flow of water is then normal.

Some three years ago I placed with a manufacturer a design for an oxygenator, but feeling some distrust withheld the feature of the sliding jet, though I mentioned it. It was well that I did withhold it, for not only did I lose my apparatus but the idea was stolen, though I retained the secret of the true mode of operation. The sliding jet is indispensable to success. In a locality in the north of France a system of oxygenators installed at great expense afterwards necessitated the modification of a great part of the plumbing and changes in the size of jets, all of which is obviated by the sliding jet.

SCRAPER FOR PREPARING FISH FOOD.

Fish culturists know that it is not a very agreeable or easy task to extract the pulp from the spleen of horses or beeves, and that it is, moreover, a very long and fatiguing operation if a knife, spoon, or any such instrument is used. For my part, having some 15 kilograms and sometimes more of spleen to scrape, I endeavored to find a readier means.

My device somewhat resembles a block plane in shape, with 5 blades protruding their full depth. I had to seek a long time for blades of requisite flexibility, shape, and size, and to fit them in proper place and at proper inclination. It will be seen that these blades have not all the same shape. This is because each has its definite place of contact, none scraping directly on the spot which the preceding blade has scraped. Otherwise the pulp would be immediately torn at the first stroke of the scraper. I have likewise overcome the other difficulties encountered at the beginning of the attempt at this device.

The following is the mode of proceeding:

To a board, 1 meter long and 0.30 meter wide, edged with a strip 0.02 meter high to keep the pulp of the spleen from falling over the sides, is affixed at each end a transverse support to raise it above the surface of the table on which the scraper is used. One support should be sufficiently high to permit a small receptacle to be placed somewhat under the board, at a height of 0.10 meter approximately, while for the other support a height of 0.03 meter would be sufficient. The board will thus be inclined.

At the lower end a narrow board is attached flat by means of a hinge at the farther side. This small board is 0.05 to 0.06 meter wide, of the same thickness as the big board, and in it are fixed 10 to 12 sharp points 0.02 meter long, spaced 0.015 meter apart. This board swung back, the spleen is placed flat on the larger board, some 0.03 or 0.04 meter of it falling over the end. The small board is then swung forward and its points, piercing the spleen, will keep the latter in place during the scraping. A small hook at the end holds the small board in position to keep the spleen from slipping. The thin skin around the spleen is taken off with a knife and the spleen is cut longitudinally several times.

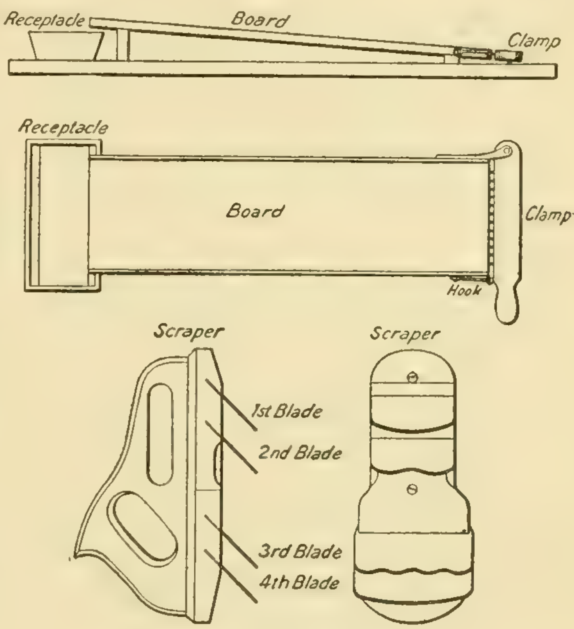

FIG. 6.—Scraper for preparing fish food.

The scraper is manipulated in the manner of a plane. The spleen should be turned end for end, if need be, to scrape the part which had been held under the toothed board.

This implement may seem an odd device, but it is remarkable how rapidly the spleen pulp is extracted. Two to three minutes are sufficient for the operation, with a spleen weighing 0.80 kilogram. It should be added that this pulp does not contain any remnants of spleen cells, as might be supposed.

If the spleen is frozen in winter and it is not feared that the nutritive qualities of the raw flesh or the spleen pulp might be decreased, it may be immersed for a few minutes in hot water before being scraped and the operation will be still more rapid.

Several establishments make use of this scraper because their proprietors have seen me use mine. I have ordered several from a manufacturing firm.

NEW METHODS OF TRANSPORTING EGGS AND FISH

By Walter S. Kincaid

General Superintendent of State Fish Hatcheries, Denver, Colo.

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

NEW METHODS OF TRANSPORTING EGGS AND FISH.

By WALTER S. KINCAID,
General Superintendent of State Fish Hatcheries, Denver, Colo.

HANDLING GREEN EGGS OF TROUT.

This method consists of packing the eggs in a case containing 4 trays, each about 8 by 20 inches, each tray containing 10 cells about 4 inches square, or 40 cells in each crate, the bottom of each tray covered with brass screen cloth to allow water to drain off and also to prevent rust. Each cell carries 4,000 green trout eggs, and there are thus 160,000 in the entire crate. In packing the eggs in the cells, make a nest of moss in each cell; place cloth down firmly in cell, leaving top of cell open; pour just 4,000 eggs in cell, fold cloth carefully over them, and then fill cell to top with moss. Before placing trays in case make cushion of about one-half an inch of moss in bottom of case. After placing trays in case set perforated ice tray on top of eggs, fill ice tray with chopped ice, and the eggs are ready for transportation either by pack horse, wagon, or rail.

This crate when packed ready for shipping weighs 81 pounds.

The advantage claimed for this method is the economy in weight and space in handling green trout eggs successfully either on pack horses, by wagon, or by rail.

HANDLING EYED TROUT EGGS.

This method consists in removing the cell trays and using the flat tray before described.

What is claimed for this method is again the economy in weight and space. The case being canvas-lined and with heavy felt cloth attached to the zinc inner lining, and having an air space between that and the egg trays, insures the eggs against heat or cold while in transit when properly iced and cared for.

This case when packed ready for transportation weighs about 80 pounds.

APPLIANCE FOR AERATING WATER IN TRANSPORTATION.

This device consists in attachments to the bottom of the can, one on each side about one-half inch thick, causing the can to rock continually from side to side with the slightest motion of the car, the water in the can assisting in the motion after once started, thus aerating itself without the necessity of an assistant while the train is in motion.

We claim that this device is very effective, simple, and inexpensive.

FISHWAYS

By H. von Bayer, C. E.
Architect and Engineer, United States Bureau of Fisheries

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

FISHWAYS.

By H. VON BAYER, C. E.,
Architect and Engineer, United States Bureau of Fisheries.

GENERAL PRINCIPLES OF FISHWAY CONSTRUCTION.

With the development in late years of water power for commercial enterprises on an economic basis, with the construction of canals for cheapening the transportation of freight, with the proposition of irrigating the otherwise waste lands of the country—all of which improvements call for the erection of dams across our rivers—the steady decrease of fish life in the waters above said dams or other obstructions has become more and more apparent, and the question has presented itself how to enable the fish to ascend to the headwaters of rivers in order to reach their spawning grounds for the propagation of their kind or to follow their migratory habits in search of food as heretofore. This question is being best met by the construction of suitable fishways.

The underlying principle in the construction of fishways is the retardation of the current velocity of a waterfall so as to enable fish to surmount it. Innumerable devices with that end in view have been invented and proved more or less successful. Certain physical conditions in the location and a proper method of construction are the important factors.

Of the physical conditions, the two principal ones are (1) accessibility of the fishway free from disturbance, its outlet being located in a pool at the bottom of the falls where fish would naturally pass in ascending the river, and (2) an abundant discharge of water through the outlet so as to attract the fish. It is to be noted that fish as a rule do not ascend rivers at low-water stage, but between mean and high water, and preferably during sunshine and warm weather.

In style of construction fishways may be classed in four systems:

I. The inclined plane system, in which a series of baffle or deflecting plates are so arranged in an inclined flume as to cause the water to follow in its descent a long sinuous route.

II. The pool and fall or step system, in which the water is brought down to a lower level by a series of short falls with intervening pools.

III. The counter current system, in which the descending volume of water is being checked by meeting a current opposing it at certain intervals.

IV. The lock and gate system, in which a higher or lower level is reached through one or more locks operated by gates.

In all four systems of fishways certain general rules governing the construction must be observed.

1. The slope of a fishway built on the inclined plane system should not be steeper than 1 foot vertical to 10 feet horizontal; the pool and fall system, as well as the counter current system, should not have a slope of more than 1 vertical to 4 horizontal, so as to insure a current velocity of not exceeding 10 feet per second in any portion of the fishway. The lock and gate system deals merely with a vertical lift. The width of a fishway somewhat governs the slope, and the wider the fishway the more gradual the slope should be.

2. The available volume of water and the size of the fish must be considered in the dimensions adopted for the fishway; small fish, like herring, bass, trout, etc., may not require over 6 inches in the clear at the narrowest points or openings in the fishway, while for large fish, like shad, rockfish, salmon, etc., the clearance spaces should not be less than 9 inches in any direction.

3. A fishway for small fish does not need to be more than 2 feet wide by about 1 foot deep, while that for large fish ought to have a least width of 4 feet with a depth correspondingly large.

4. Plenty of light should be admitted in a fishway, both for maintaining therein the natural conditions of the water, and in order that the interior may easily be inspected and any foreign matter removed.

5. A fishway in all its parts should, by the action of the current of water passing through it, be as nearly as possible self-cleaning of all sand, gravel, mud, and rubbish.

6. The water supply of a fishway should be ample and the same, or nearly so, at both ordinary high and low water stages, avoiding thereby any regulating gates or other devices calling for the services of an attendant.

7. The top and sides of a fishway should be above ordinary high water.

8. The fishway should be built very strong and be well protected against the destructive effects of freshets, drift logs, ice, etc.

9. The intake and outlet should be well submerged and the former protected against floating débris, etc., by a suitable grating.

The location of a fishway must be such that ascending fish will not be alarmed and driven off by disturbance from boats, fishermen, etc.

The material of fishways may be wood, stone, concrete, or iron, depending upon the construction of the dam, its size, the topography and nature of the site, the labor and material at hand, and the funds available.

VARIOUS FISHWAY DESIGNS.

I. INCLINED PLANE SYSTEM.

Figures 1 to 11 show a more or less sinuous course for the water current down an inclined plane, to retard the current velocity.

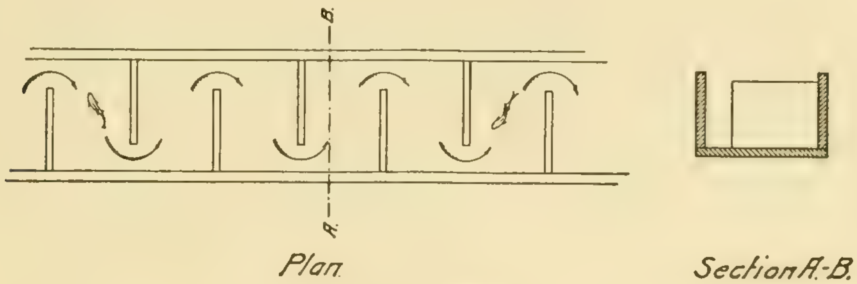

FIG. 1.—Roberts.

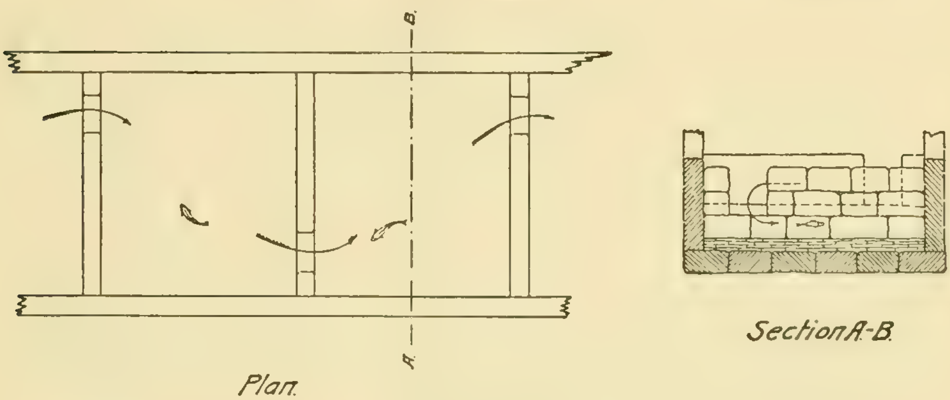

FIG. 2.—Smith.

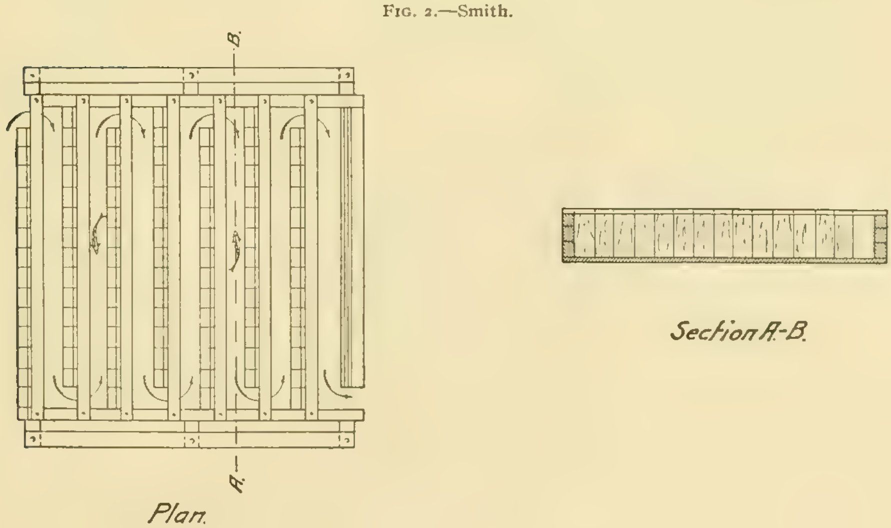

FIG. 3.—Wheeler.

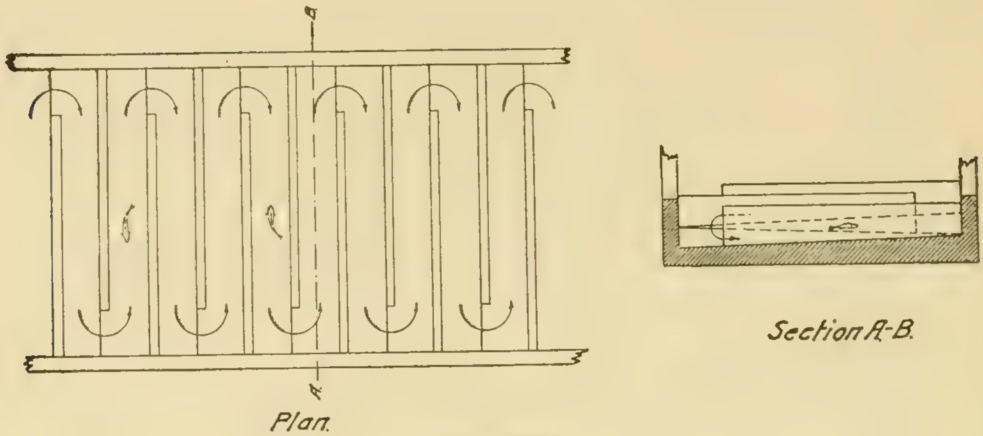

FIG. 4.—Steck.

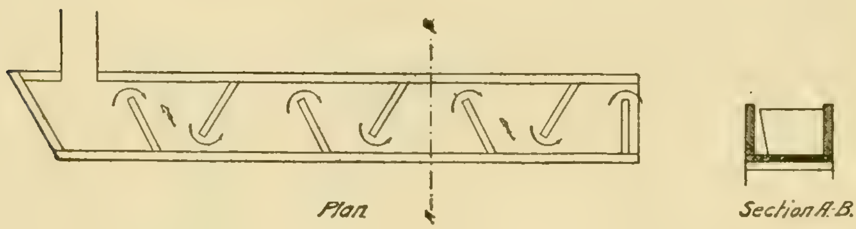

FIG. 5.—Foster.

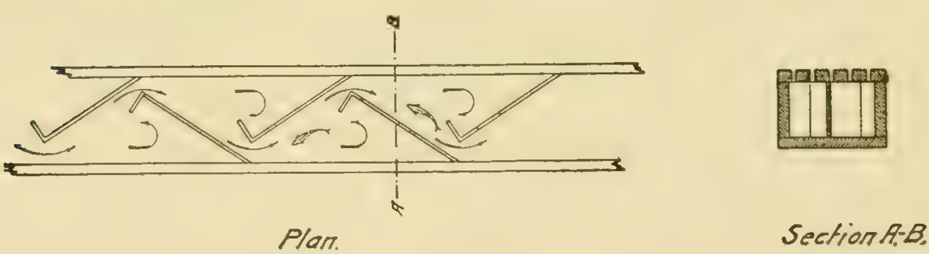

FIG. 6.—Rogers.

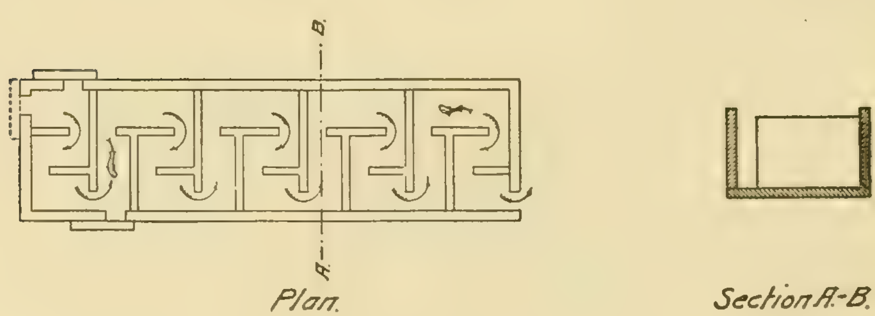

FIG. 7.—Brackett.

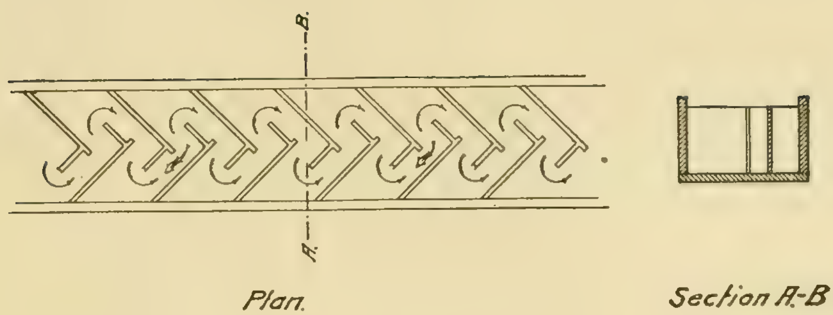

FIG. 8.—Swazey.

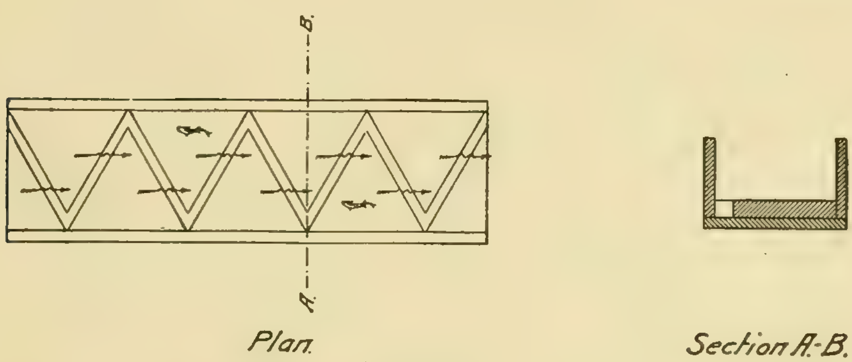

FIG. 9.—Brewer.

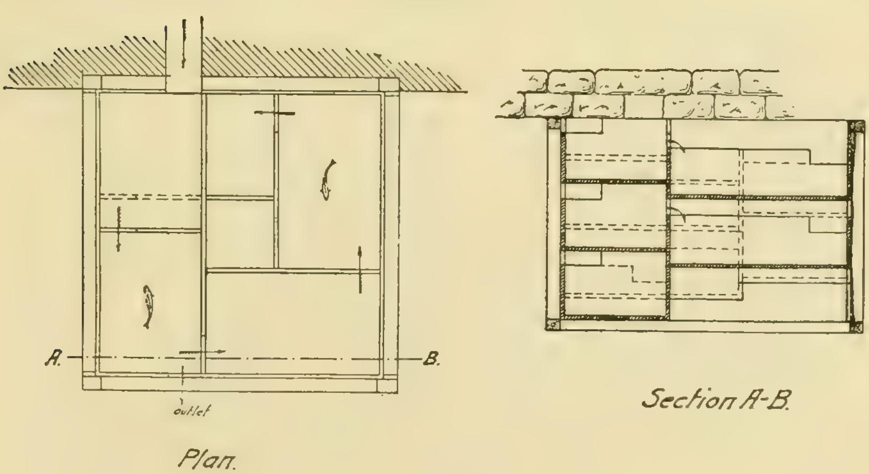

FIG. 10.—Shaw.

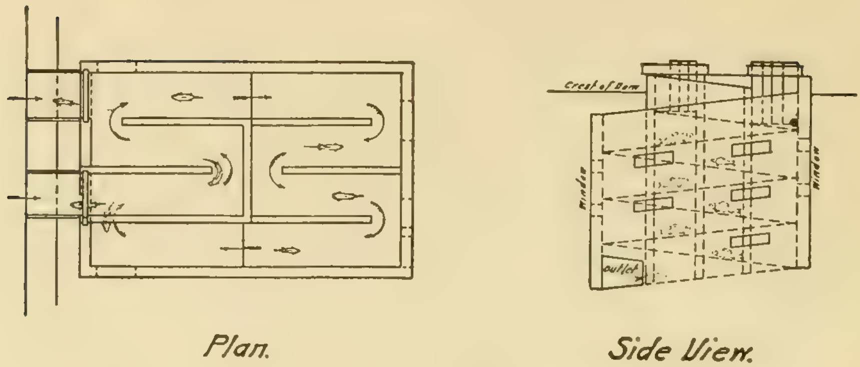

FIG. 11.—Atkins.

Under system I may be reckoned also the fishways for young eels, which consist merely of an inclined pipe from 4 to 6 inches in diameter, or a narrow flume, which is filled with loose gravel and pebbles, with fascines of brush and saplings, or with a mixture of both, through which the young eels can readily pass.

II. THE POOL AND FALL, OR STEP SYSTEM.

Figures 12 to 14 show the current carried down an incline broken by steps into a number of pools of relatively still water.

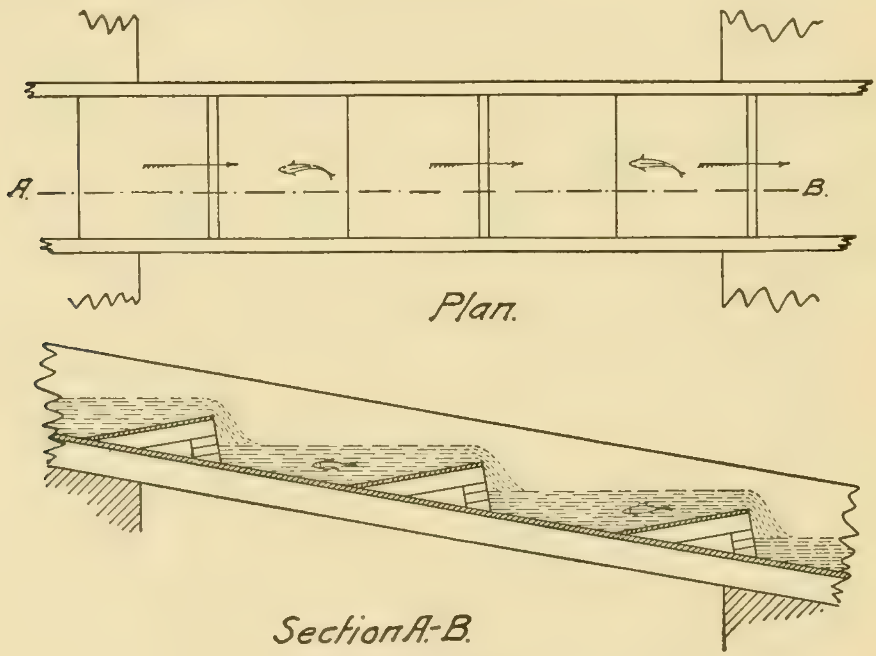

FIG. 12.—Richardson

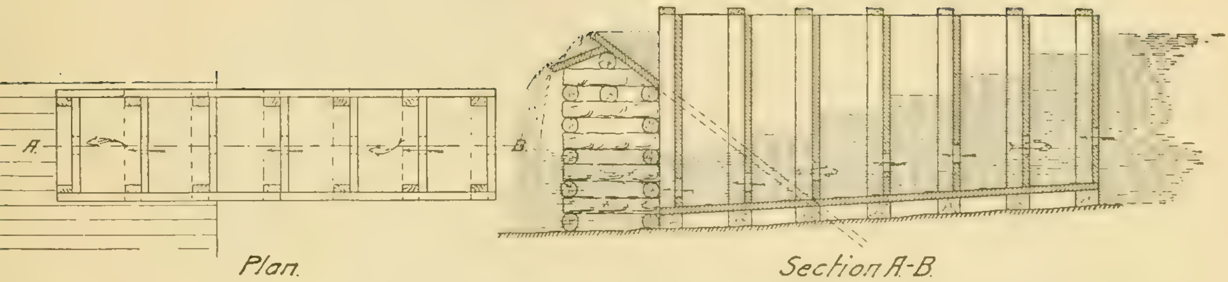

FIG. 13.—Hockin.

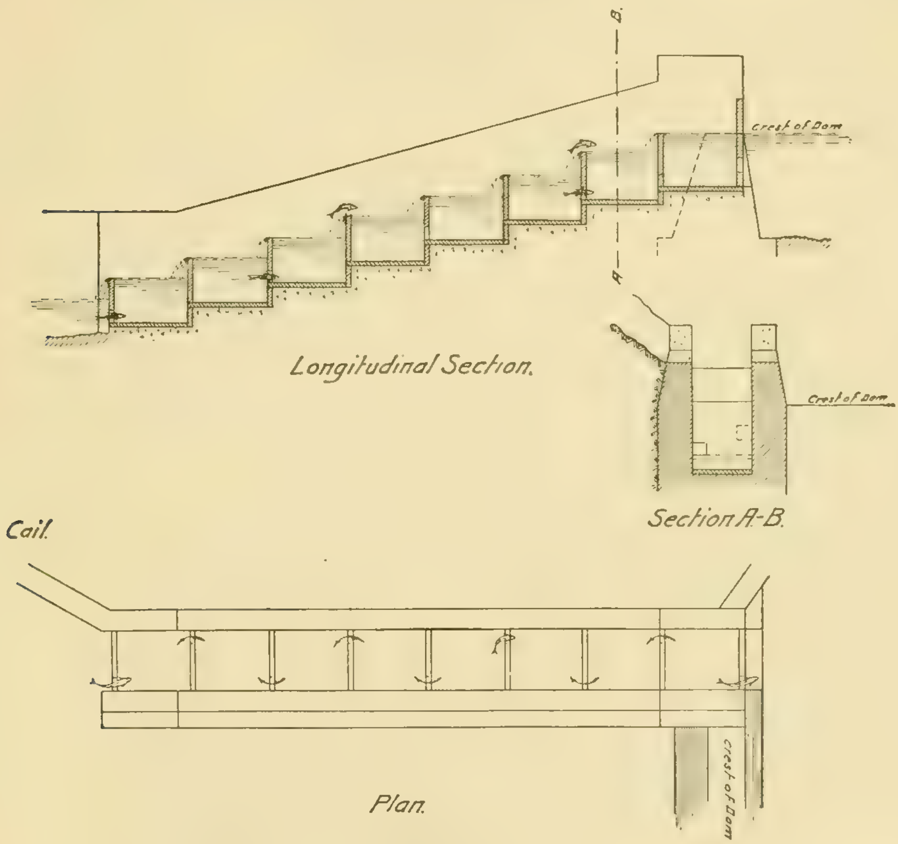

FIG. 14.—Cail.

III. THE COUNTERCURRENT SYSTEM.

Figures 15 to 17 show the action of a twofold current, the parts opposing each other and thereby retarding the velocity of the two combined.

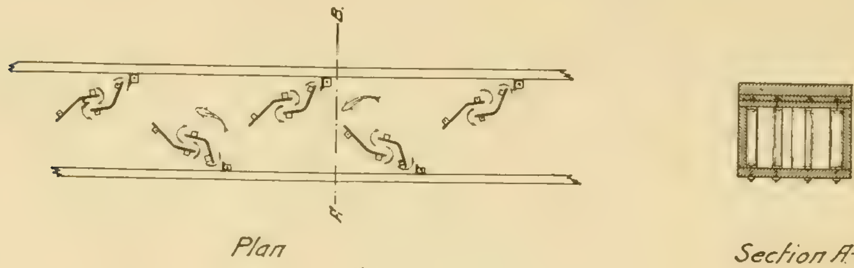

Fig. 15.—McDonald.

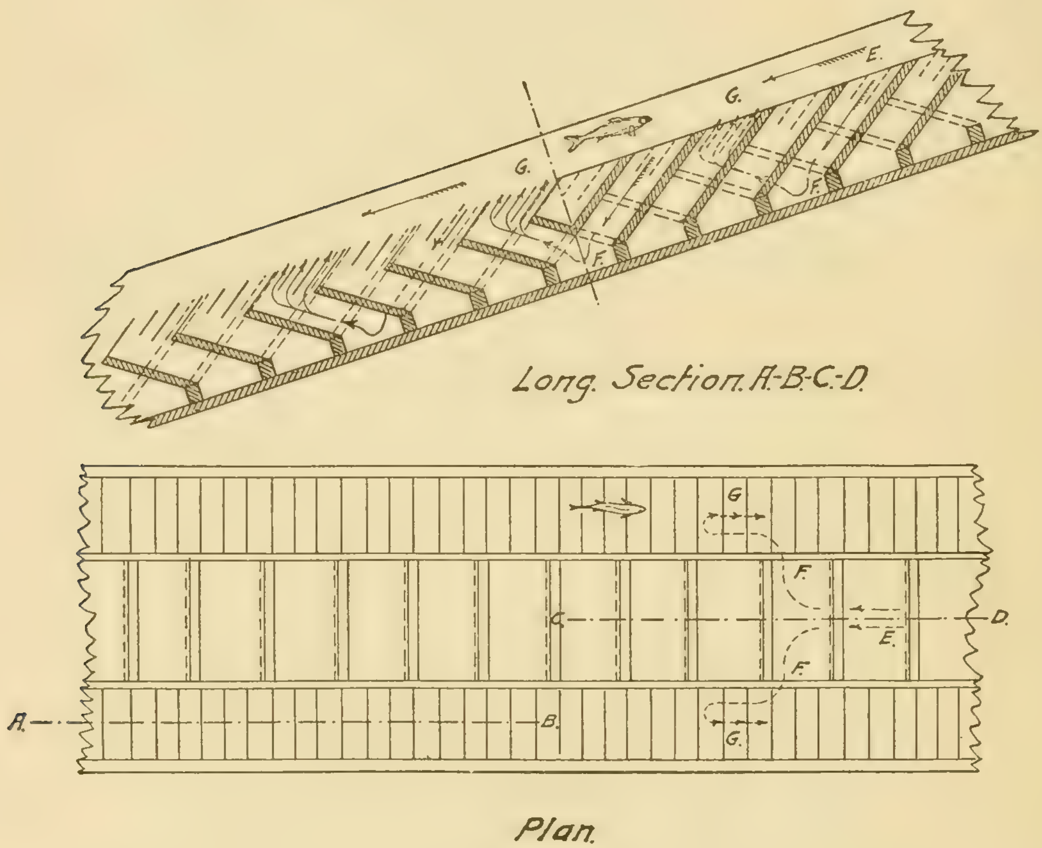

Fig. 16.—McDonald.

In this fishway the water passes through a series of centrally located buckets inclined downstream into another series of buckets located at either side of the fishway, provided on top with deflecting plates, whence it issues in an upstream direction, opposing the down current, as shown by arrows. The fishway may be protected by an iron grating over which the fish ascend.

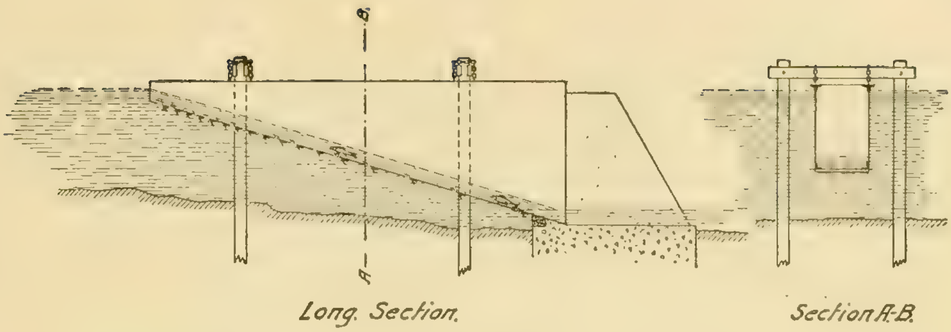

FIG. 17.—Caméré.

This fishway consists of a suitable chute submerged in the water as shown, and is provided with a series of slits in the bottom through which a current of water enters under a static pressure opposing the descending current of water in said chute. The design was later on improved by adding to the slits in the bottom a corresponding number of slits in the sides.

IV. LOCK AND GATE SYSTEM.

Figures 18 and 19 show the admission of a body of water by gates into a lock chamber and out of it to a lower level, whereby fish are being lifted vertically in ascending a stream.

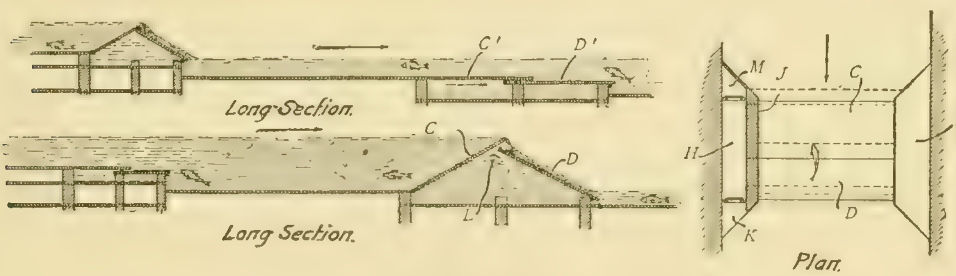

FIG. 18.—Kirk.

Process: If valve M is opened chamber HH will fill with water, and, by means of passageways under abutment J, the water will pass into chamber L and force gates CD to rise. The gates will rise until the water reaches an overflow opening at L. If valve M is closed and K opened, the water under the gates escapes and they will go down to position C′ D′. Making the lower set of gates double the height of the upper set and arranging for an automatic alternate rising and lowering of the gates at certain intervals of time, the fish are enabled to pass upstream through these locks thus forming.

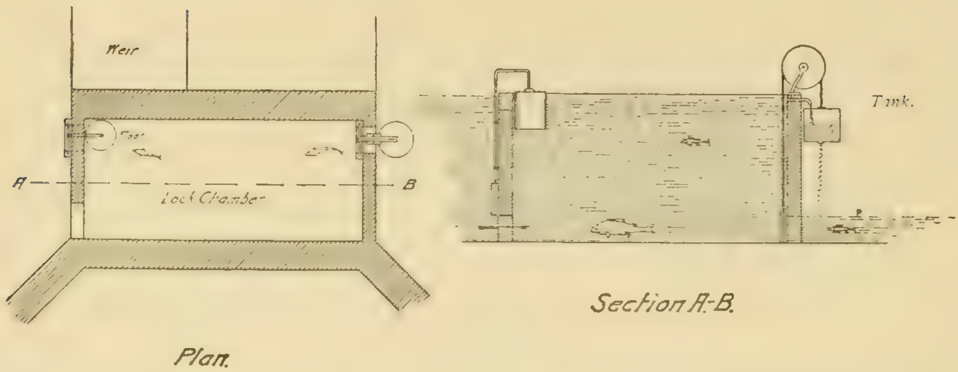

FIG. 19.—Recken.

Here the water chamber is shown full, and a water tank at the right is filling. When latter is full it will descend of its own weight and raise the gate, to which it is attached by means of a cable over a grooved wheel, allowing lock chamber to empty to lower level. When lock chamber is empty a float and gate in the upper partition, rigidly connected together, will be down; water tank being cut off from supply will also become empty, the water dripping gradually out of the bottom opening as shown. Supply through a notch in upper partition will begin to fill lock chamber and lift float and gate, thus repeating the process described.

THE IMPROVED CAIL FISHWAY.

The "Improved Cail fishway" (fig. 20) is a combination of the inclined plane system with the pool and fall or step system. It consists of a series of compartments arranged in steps and separated by a number of cross partitions, which are provided with suitable orifices at the bottom, alternating successively from side to side, so as to allow the fish, according to their individual habits, to ascend the fishway by either leaping over the small waterfalls over the cross partitions or by darting through the orifices, at the same time enabling them to rest in the compartments in comparatively still water.

The present improved Cail fishway embodies certain improvements made by B. M. Hoecht, of Germany, who built at Hameln, on the lower Weser, a large fishway on the Cail principle, constructing it of masonry and concrete, with a fall of about 1 foot in 8 feet. The design was brought to another form by the present author, and is now the pattern recommended by the United States Bureau of Fisheries. Its construction embraces all requirements for a fishway, as enumerated above, viz:

1. The slope of the fishway as per figure 20 is in a proportion of 1 vertical to 4 horizontal, the fall from compartment to compartment is 1 foot 6 inches, and the greatest velocity of the current through the orifices is less than 6 feet per second.

NOTE.—$V=m\sqrt{2gH}=0.57 \times 8 \times 1.23=5.6$ feet per second. V is the velocity in feet per second; g, acceleration per second of a falling body, 32.16 feet; H, head of water column proper, 1.5 feet; m, coefficient for contraction obtained by actual experiment, 0.57.

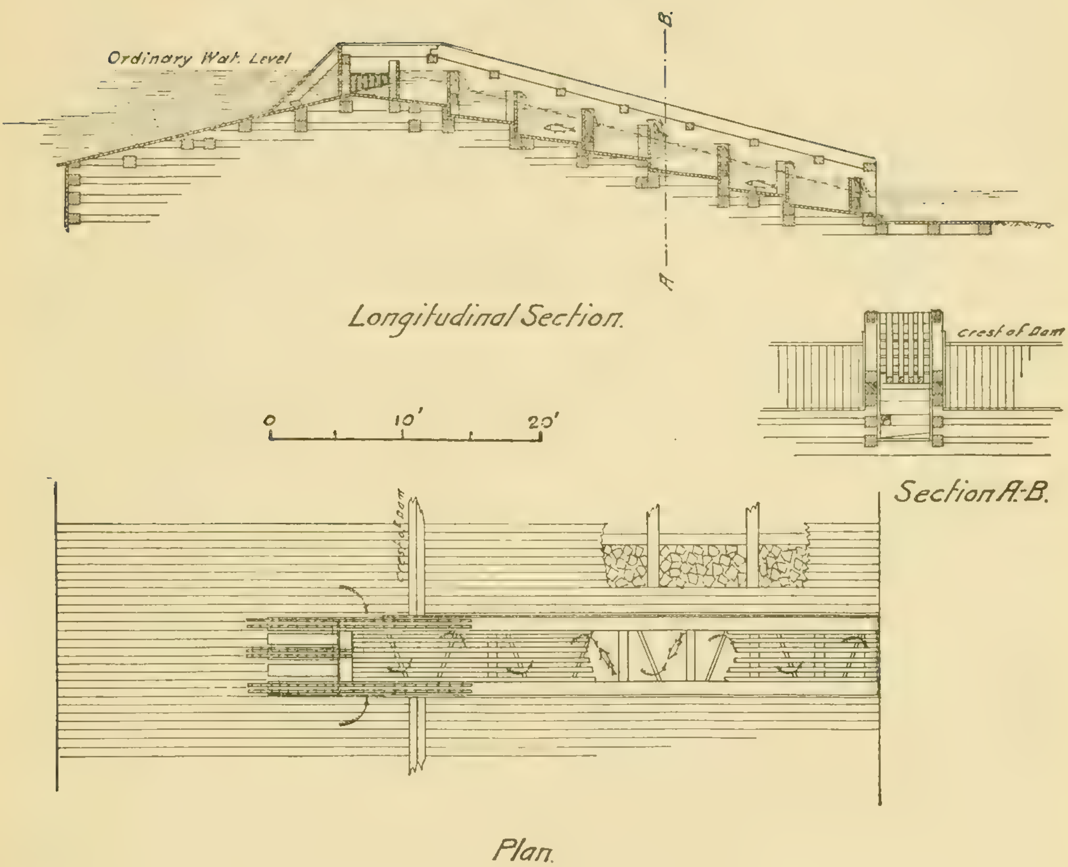

FIG. 20.—Improved Cail fishway.

2. The fishway proper is 4 feet wide inside, with orifices in the cross partitions varying from 12 inches by 12 inches at the outlet to 18 inches by 18 inches in the uppermost cross partition near the inlet, allowing fish of the size of shad, rockfish, salmon, etc., as well as smaller fish, to pass through.

3. The mean depth of water in the compartments is 3 feet.

4. Plenty of light is admitted through the open spaces between the protecting timbers on top, thus allowing ready inspection and easy removal of any débris lodging in the fishway.

5. The cross partitions are set at a slight angle to the axis of the fishway, and the floor of the fishway is slightly slanting, to bring the orifices in the lower ends of the cross partitions and cause a current in the angles formed between the cross partitions and the floor, thus automatically removing any accumulation of sand, gravel, mud, and rubbish.

6. The crest of the uppermost cross partition is at an elevation equal to that of ordinary high water, so as to keep the water supply in the fishway nearly the same at ordinary and high-water stage, avoiding thereby the need of any regulating gates.

7. The top and sides of the fishway are kept well above ordinary high water, to prevent the flooding of the fishway and possible injury.

8. Heavy timbers strongly bolted together are used in the construction of the sides and top of the fishway when built of wood, with strong fender pieces above the intake secured to the dam with heavy iron straps, to protect it against drift ice and logs during freshets.

9. Both the intake and the outlet are well submerged below mean water level, and the intake is protected against floating débris, etc., by a substantial iron grating.

The necessary volume of water for supplying a fishway of the dimensions as described here should not be less than 8 cubic feet per second.

The construction of the fishway is alike adapted to wood, masonry, or concrete, and it may follow either a straight line or have angles and returns, as the local conditions may require. The construction is applicable to the various forms of existing dams and natural waterfalls. The cost of construction of a fishway built of timber as per illustration under ordinary conditions will be about $1,000.

Fishways of this design have proved quite efficient and have been built in late years at various dams in the Susquehanna River and its tributaries; others, built of concrete, were constructed at a number of the large electric-light and power dams in several of the states. (See fig. 21, p. 1056–1057.)

REGULATIONS FOR THE CONSTRUCTION OF DAMS AND FISHWAYS.

The United States Government does not exercise any jurisdiction over waters not navigable, the construction of dams and fishways in these waters being regulated through the state laws. Most of the state legislatures have enacted such laws and fixed certain penalties for violation of the same. For navigable waters, an act of Congress approved June 21, 1906, to regulate the construction of dams provides as follows:

SECTION 1. That when, hereafter, authority is granted by Congress to any persons to construct and maintain a dam for water power or other purposes across any of the navigable waters of the United States, such dam shall not be built or commenced until the plans and specifications for its construction, together with such drawings of the proposed construction and such map of the proposed location as may be required for a full understanding of the subject, have been submitted to the Secretary of War and Chief of Engineers for their approval. * * * *Provided,* That in approving said plans and location such conditions and stipulations may be imposed as the Chief of Engineers and the Secretary of War may deem necessary to protect the present and future interests of the United States, which may include the condition that such persons shall construct, maintain, and operate, without expense to the United States, in connection with said dam and appurtenant works, a lock or locks, booms, sluices, or any other structures. * * *

SEC. 3. That the person, company, or corporation building, maintaining, or operating any dam and appurtenant works, under the provisions of this act, shall be liable for any damage that may be inflicted thereby upon private property, either by overflow or otherwise. The persons owning or operating any such dam shall maintain, at their own expense, such lights and other signals thereon and such fishways as the Secretary of Commerce and Labor shall prescribe.

SEC. 4. That all rights acquired under this act shall cease and be determined if the person, company, or corporation acquiring such rights shall at any time fail to comply with any of the provisions and requirements of the act, or with any of the stipulations and conditions that may be prescribed as aforesaid by the Chief of Engineers and the Secretary of War.

SEC. 5. That any persons who shall fail or refuse to comply with the lawful order of the Secretary of War and Chief of Engineers, made in accordance with the provisions of this act, shall be deemed guilty of a violation of this act, and any persons who shall be guilty of a violation of this act shall be deemed guilty of a misdemeanor and on conviction thereof shall be punished by a fine not exceeding five thousand dollars. * * *

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[a] Since this writing a most interesting article, "La genèse d'une échelle à poissons nouvelle," by G. Denil, has appeared in the Bulletin Populaire de la Pisciculture, no. 9, 1909, p. 155–183, Paris, 1909.

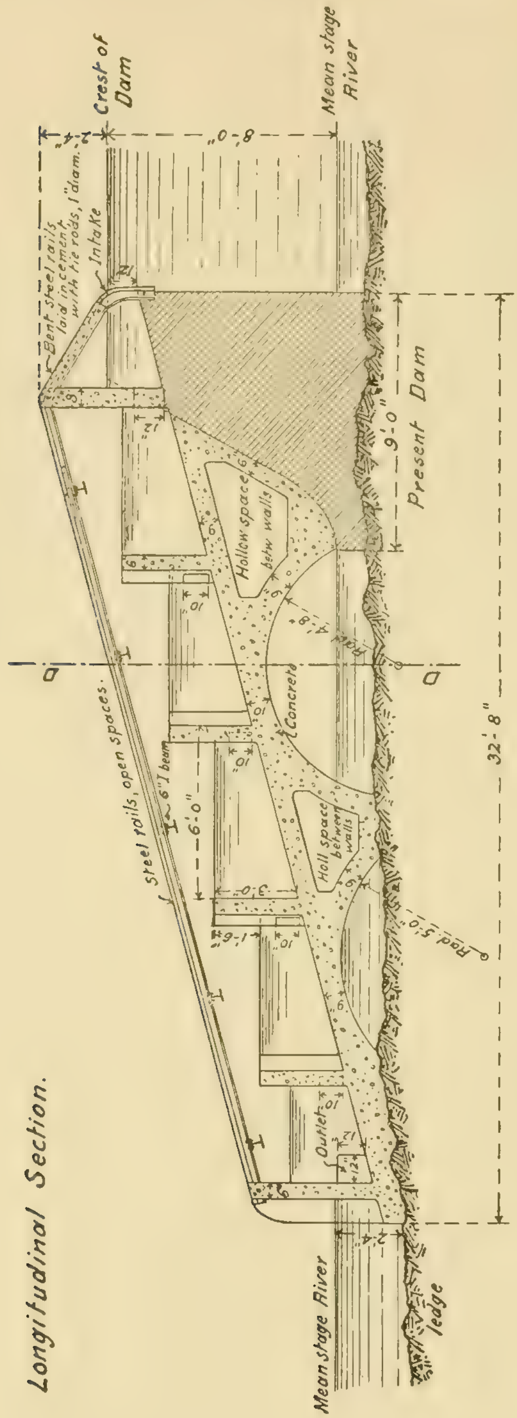

Fig. 21.—Adaptation of the improved Cail fishway, constructed of concrete. Designed by H. von Bayer for the Shenandoah River, in Virginia.

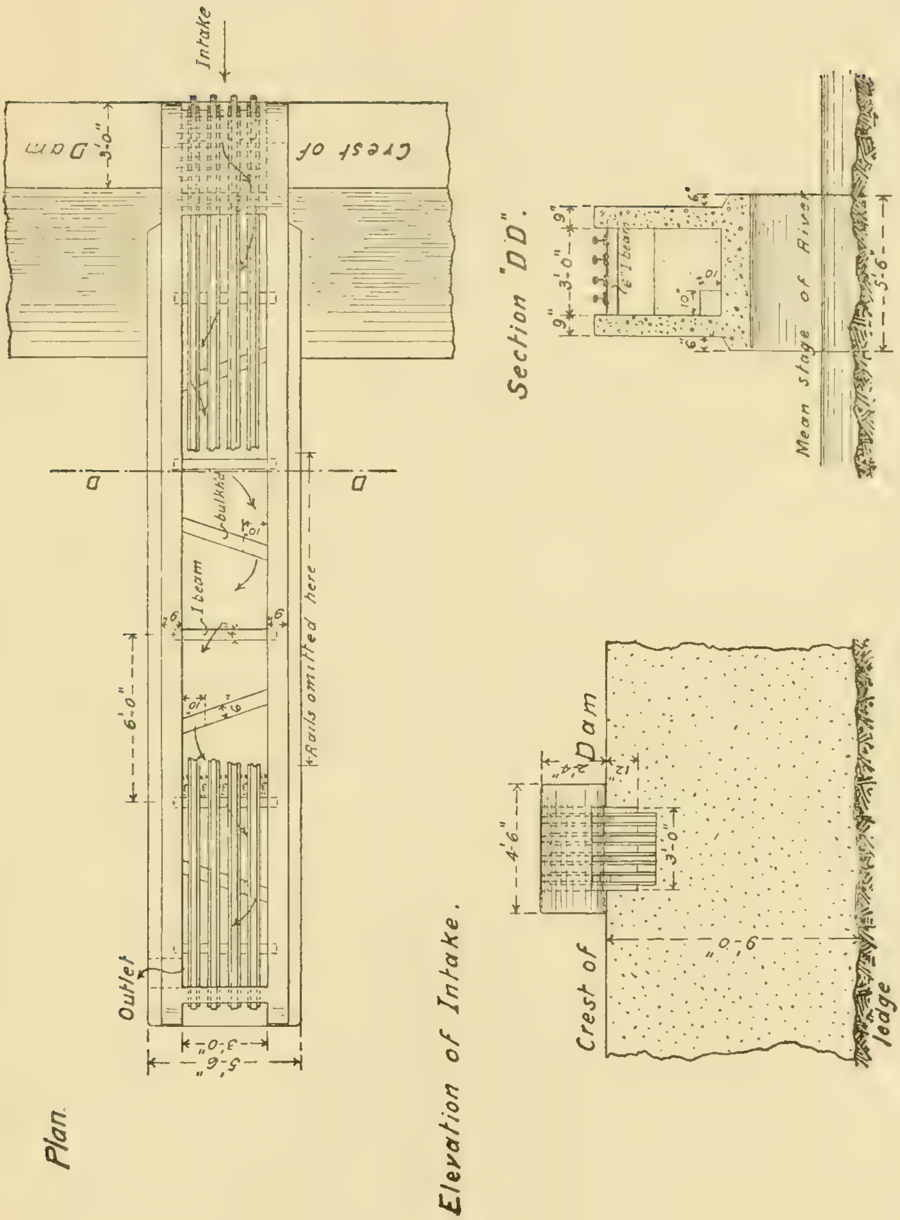

FIG. 21.—Continued.

A PLEA FOR OBSERVATION OF THE HABITS OF FISHES AND AGAINST UNDUE GENERALIZATION

By Theodore Gill, Ph. D., LL. D.

Honorary Associate in Zoology, Smithsonian Institution

Address before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

A PLEA FOR OBSERVATION OF THE HABITS OF FISHES AND AGAINST UNDUE GENERALIZATION.

By THEODORE GILL, Ph. D., LL. D.,
Honorary Associate in Zoology, Smithsonian Institution.

I have been requested to address the International Fishery Congress, but on account of the extensive programme provided for it brevity will be recognized as a virtue if not demanded as a requisite. I shall therefore confine my remarks to a plea for the presentation of much wanted information respecting the habits of fishes in general, but especially those which are the objects of pisciculture. Indeed such knowledge is a necessary prerequisite for successful pisciculture and should be made public in the interests of industry as well as of science. Nevertheless, essentials of some of our most esteemed fishes are scarcely known beyond a very small circle of pisciculturists. The crappie of America (*Pomoxis sparoides*) is a notable case. It is one of our best fresh-water fishes, but the accessible accounts of its habits are extremely meager and no account has been published of its sexual intercourse, the preparation of a nest, or the care of the eggs and young by the parent fish.

Too much care can not be given to the detailed observation of the economy of any fish, for differences between related species may exist which might be least foreseen. For instance, two silurids occur in Europe which are so near each other that they have been long nominally confounded; they are the common wels of central and eastern Europe and the glanis of Greece. Notwithstanding their great morphological similarity, they differ remarkably in their habits, for the wels takes no care of its eggs, while the male of the glanis exercises paternal supervision for a prolonged period. Why the statement that the two have been nominally confounded has been made will be explained later. One more example of contrast may be cited. One of the best known and most generally published accounts of parental care among fishes is that one, three quarters of a century ago (1828), attributed to the hassars (*Callichthys* or *Hoplosternum*) by Dr. John Hancock. Yet the species of a related genus (*Corydoras*) have quite different habits in general as well as in courtship and oviposition; no care is exercised over the eggs by either parent.

Fishes that do exercise parental care differ as to the manner in which it is shown and the length of time it is maintained. Most, if not all, of our centrarchids, for instance, protect their eggs, but there is a difference between species or genera otherwise. It was first declared some years ago (in 1903), by Prof. Jacob Reighard, that the black bass continues the care begun with the nest and new-laid eggs till the young fishes have acquired a considerable size, while sunfishes of the genera *Eupomotis* and *Lepomis* discontinue care after the eggs have been hatched.

Undue generalization has been exercised also in statements respecting the relative sizes of the sexes of fishes. A celebrated ichthyologist, in an "Introduction to the Study of Fishes," positively declared that "it appears that in all teleosteous fishes the female is larger than the male," and yet there are many exceptions to this statement. Indeed, in most fishes whose males are differentiated by marked secondary characters, so far as known the male is larger than the female. Even in some of our common cyprinids such is the case; the species of *Semotilus*, often miscalled "chub" or "horned dace," are examples. The males of those species are stone-rollers, thereby preparing a nest for the eggs. An undue generalization might be extended from the examples for it might be assumed that there was coordination between the size and the care-taking function. In contrast, however, the lumpsucker (*Cyclopterus*) confronts us; in this case the male is much smaller than the female. In fact, we are in much need of definite information as to relative sizes of fishes generally.

A common African fish, the bolti (*Tilapia nilotica*) of Egypt, has males larger than the females, and presumably many others of the same large family do likewise. In this case the males prepare a nesting place but the females act as nurses by taking their eggs into their mouths for incubation.

There is a tendency among almost all men to too great generalization and to an assumption that, because certain forms manifest special modes of behavior or action, others do so also. Thus, because the fishes that had been noticed by early observers did not take care of their eggs but left them after deposition and fertilization to unaided nature, it was assumed that all fishes were alike neglectful. Later, it was found that some forms did take charge of their eggs and then it was assumed that it was the females, simply because among mammals and birds the females do so. Our catfishes and sunfishes, for example, were discovered to care for their eggs, but the old observers invariably credited such care to the females. Meanwhile it was ascertained that it was really the males, only or chiefly, that assumed such charge, and as such was found to be the case also among the sticklebacks and various other fishes, the generalization was conceived that in the case of all fishes that care for their eggs it was the male that was the guardian.

This generalization was applied to the cichlids of Africa and Palestine and, in various accounts of the habits of the bolti and similar fishes, reputable writers, such as Günther and Lortet, especially credited the males with exclusive parental care. Subsequent dissections of the same species and other species observed by these naturalists revealed the fact that in all the cases in question the females took charge, taking their eggs in their mouths and caring for them and the newly hatched young until they had attained a considerable size. In fact, so far as the cichlids are concerned, numerous African species have now been examined, and for all of those so examined the females have been ascertained to be the egg-carriers. Let it not be assumed, however, that all the other cichlids take such care of the young and that all American species do so, as well as the African. Indeed, even now it is known that certain South American species provide for their eggs in nests made by heaping pebbles over their eggs or otherwise preparing the bottom, rather than by oral incubation. But more than this is not known and we are ignorant of the parts played by the respective sexes.

The tendency to undue generalization has been exhibited in a striking and even amusing manner in the case of two European fishes already referred to, the wels of Germany and the glanis of Greece. The wels had long ago been declared by many observers to exercise no parental care after deposition and fertilization of their eggs. It happened, however, that Aristotle, over twenty-two centuries ago, gave elaborate details of the glanis and the care taken of the eggs by the male parent. Instead of those accounts, which bore the impress of observation and truth on their face, serving as a check to identification, it was assumed by some of the greatest of modern ichthyologists, such as Cuvier, Valenciennes, and F. A. Smitt, that the wels and the glanis were of the same species; the Frenchmen declared that Aristotle's account "borders a little on the marvelous" and the Swede reechoed with the remark that "it is now regarded as dubious." Yet over half a century ago (1856) Agassiz declared that Aristotle was right and that the Aristotelian fish differed, not only specifically but generically, from the wels. Later, comparative descriptions and illustrations of the Grecian species were published; nevertheless the two continued to be confounded in Europe under the same name. But recently a new attitude has been assumed otherwise. At last it has not only been acknowledged that the facts recorded by Aristotle were credible, but assumed that what was true of the glanis must be true of the wels; in a reference to the species made by a distinguished French ichthyologist this year the wels ("l'enorme Silure d'Europe") is credited with paternal instinct and attention. Thus has generalization been carried to an extreme and assumption piled on assumption. One further assumption apparently was that because the glanis was not in a European

museum it could not be a distinct species, and another that the American authors were incompetent to determine the species.

It might be thought that related species would agree at least in the character of their eggs and oviposition, but exceptions to this also occur. A notable case is manifest among the clupeids. There are several species of the northern seas so closely related that they are associated by most ichthyologists except in America in the same genus—*Clupea*. Nevertheless there are remarkable differences between species in their eggs, as well as in the manner of depositing them. The typical herrings (*Clupea harengus* and *Clupea pallasi*) have opaque eggs destitute of oil globules, deposited in the sea in water of moderate depth and adhering in masses to foreign bodies at the bottom; the pilchards (*Clupanodon pilchardus*, etc.) have translucent eggs, buoyant by oil globules, and cast near the surface of the sea often quite far from land and there hatched; the shads (*Alosa* species) leave the sea and ascend rivers to deposit their eggs near or on the bottom in fresh water; the alewives and hickory shads (*Pomolobus*) are also anadromous and agree in most respects with the shads.

Another requisite, too often overlooked for the successful historian of a fish's habits, is that the species in question should be correctly identified or the means for identification furnished. Many instances might be given of interesting details of habits of animals worthless to science because the species are not recognizable. Only one such need be mentioned and that because it has recently come up for notice. Many years ago (in 1874) a French amateur naturalist, Carbonnier, published some remarkable details of the breeding habits of fish received from New York which he called "la Fondule (*Fundula cyprinodonta*, Cuv.)." I have been frequently appealed to for information as to the proper name of that fish. No such fish was described by Cuvier and apparently the Frenchman had been informed by some one, in an offhand manner, that it was a *Fundulus*—a cyprinodont—and had been satisfied with the suggestion and even misinterpreted the statement. In fact, the fish was not a cyprinodont at all, although having a considerable superficial resemblance to one, but an umbrid, the common *Umbra pygmæa* of New York. To this day, so far as published records show, Carbonnier is the only man who has succeeded in breeding this fish, but his record was long unusable because it was not known what fish he really had.

Another fault we must take care to guard against is the counterbalancement of a difficulty against a certainty. Many examples of this are to be met with in the history of the common eel. Several are still persistent.

The breeding resorts of the eel of northern Europe have been discovered within the last two years, thanks to the International Council for the exploration of the North Sea and the excellent work of Johannes Schmidt; they are in the ocean at "depths of at least about 1,000 meters (corresponding to a pressure

of ca. 100 atmospheres)." In other words, eels can not mature their gonads nor breed in fresh water, yet there are many persons to the present day who maintain that they must do so, because they can not perceive how eels could be found in ponds and waters isolated from rivers communicating with the ocean. There are many ways in which they might be diffused, but that need not concern the biologists; that they must have originated in the ocean is certain.

No eels which have once spawned have been found in fresh waters, but because large eels have been seen at some place pursuing an upward course, strenuous claims have been made that some do ascend rivers after spawning; here again we have a difficulty (but an extremely slight one) balanced against a counterfact.

We have still much to learn about our most common and longest-known species. The *Apogon imberbis* or *rex-mullorum* is a Mediterranean fish which had never been regarded as of much interest. Several years ago (1903), however, a French naturalist (L. Vaillant) found its own eggs in the mouth of the male of a related Caribbean fish (*Cheilodipterus affinis*) and quite recently the United States Deputy Commissioner of Fisheries (Hugh M. Smith) found also in the waters of the Philippine Archipelago a number of species exercising oral incubation. This present month (September 1, 1908) Dr. L. Plate records the discovery of a small species of the same group (*Apogonichthys strombi*) as a commensal of the large whelk known as *Strombus gigas*.

With these facts discovered respecting congeneric species, renewed observations should be made. It would be another example of the undue generalization which has been deprecated to assume that the Mediterranean fish agreed with its relatives in oral incubation—very much more that it was a commensal. It should be reexamined till something definite can be learned of its habits during the breeding season. Fishermen may often have found individuals with eggs in the mouth and assumed that they had been taken in as food, so that the fact of none of these fish having been recorded with such eggs is a matter of minor consequence. We would have reason for surprise if it should be found that the Mediterranean *Apogon* does not exercise oral incubation, and also if other species have commensal habits like the *Apogonichthys strombi*, but positive assumption is illegitimate in both cases.

The relationship of fishes to other animals is a subject which will repay future investigation, and search may be rewarded by many cases scarcely less expected than the parasitic habit of the *Apogon*. Certain tropical pomacentrids of the genera *Amphiprion* and *Premnas* use actinizoans for shelter; the butterfish of the American coast (*Poronotus triacanthus*) harbors during its early youth under the disk of a medusa, and so does also the scad (*Trachurus trachurus*) of Europe. Still more remarkable are the fierasfers which seek

shelter and home by obtruding into the posterior end of the abdominal cavity of holothurians.

Another subject that will furnish interesting cases is courtship among fishes. Many American fresh-water fishes furnish examples. The males become more or less brilliant and assume bright liveries for and during the spawning season and variously show themselves to the females; the best known species are the sunfishes (*Lepomis* and *Eupomotis*) of different kinds, but representatives of most or all families have their special modes of action. A still more elaborate courtship was observed a decade ago (1898) by Ernest Holt among sea fishes of the genus *Callionymus*.

One fact, too often forgotten, is that there is considerable individuality among fishes and that there may be exceptions to most general propositions. Species, for instance, may prefer certain food, but if they can not get such they will act very much like human beings—take what they can get. Yet our periodicals, monthly as well as weekly, are often charged with bitter controversies because one man makes an assertion respecting habits which is denied by another who asserts that the animal in question always has certain other habits. Both may be right in their observations but wrong in contending each that the other is wrong.

Such are a few of the many interesting phenomena manifested by fishes and such a few of the special exceptions to general propositions. No men are professionally in such excellent positions for observation of the habits of fishes as are pisciculturists, and, if they would, they could add greatly to our knowledge of their ways and means; that they should do so the scientific ichthyologist and the practical fisherman must alike hope.

I conclude with a recapitulation of some of the characteristics by which fishes are distinguished among themselves and which may direct attention to points overlooked or forgotten. Any biography of a fish that is wanting in attention to any of the characteristics indicated is to such extent incomplete.

SCHEDULE FOR OBSERVATION.

Specific characters:
- Adults.
- Sexual differences.
- Relative size.
- Length.
- Weight.

General behavior:
- Character of water preferred.
- Character of ground preferred.

General behavior—Continued.
- Manner of resting.
- Manner of swimming.
- Use of fins.
- Respiration.
- Association (in schools, etc.).

Feeding:
- Kind of food preferred.
- Manner of taking.

Feeding—Continued.
- Time of taking.
- Abstinence during spawning season.
- Abstinence during cold periods.

Distribution:
- General.
- Seasonal (summer, winter, etc.).
- Migration.
- Arrival.
- Departure.
- Route of travel.
- Relative appearance of sexes.
- Schooling.

Reproduction:
- Age at maturity.
- Preliminary changes.
- Special male seasonal characters.
- Special female seasonal characters.
- Season of reproduction.
- Temperature of water.
- Preparation.
- Manner of sexual excitation.
- Nest-making.
- Parts assumed by sexes.
- Selection of place.
- Depth of water preferred.
- Manner of spawning.

Reproduction—Continued.
- Frequency of spawning.
- Behavior of males and females meantimes.
- Disposition of eggs.
- Number of eggs.
- Period of incubation.
- Retardation or acceleration of incubation by temperature.
- Care of eggs.
- Care of fry.
- Period of care.
- Food of young.

Growth:
- Development.
- Successive changes.
- Size and characters, first year, second year, third year, fourth year.

Parasites.

Diseases.

Economical value:
- Value as food and otherwise.
- Manner of capture.
- Statistics.

Legends:
- Beliefs or sayings connected with species.

DISCUSSION.

Prof. E. E. PRINCE (Canada). I feel again as if I ought to apologize for rising to speak, at the same time I am impelled out of a sense of gratitude to Doctor Gill, which all the younger workers in ichthyology and the students of fish and fisheries generally feel for one who is the Nestor of the science of fish and fisheries. It is a privilege which I think we shall long remember to have heard Doctor Gill on this occasion; and I think that on the principle of keeping the good wine to the last it was appropriate that Doctor Gill should come in even at the end of the programme. I may claim to be one of the younger workers, and I have always felt that Doctor Gill was one who gave credit to the young workers for anything they contributed to science.

I do not wish to trespass very long on the time of the congress, but I feel especially interested in Doctor Gill's reference to the development of the eel, because since I came to this congress I have received quite a long letter from Doctor Schmidt, of Copenhagen, asking about the movement of young eels in our Canadian waters, and I hope to be able to report, as indeed I have previously, certain observations of my own as to the migration of young eels up some of our Canadian rivers. Countless multitudes ascend in the summer, especially in August, and they surmount obstacles such as high falls.

The statement that one can never prophesy the characteristics of a fish as to its eggs and its young I know to be very true, and we should remember the warning which I think Sir Ray Lancaster, long ago, gave embryologists, that embryology was so full of surprises and wonders that we must never prophesy until we know. I remember, years ago, my own experience in regard to *Clupea sprattus*, for I felt as if all the herring family should deposit their eggs in a certain way, viz, on the sea bottom, because *Clupea harengus* did so; and I remember with great surprise finding that *Clupea sprattus*, the small sprat in European waters, deposited not only a pelagic or floating egg, but an egg of extreme delicacy. The egg of *Clupea sprattus* is the most delicate and most buoyant. This is surprising when one remembers the nonbuoyant eggs of the herring. Then, the fact that the smelt also deposits, like the Salmonidæ generally, not only a heavy egg, but an egg which is attached by a kind of pedestal to stones in brackish water, not a loose free egg, shows that we must investigate by actual observation and by actual study the character of the eggs and spawning peculiarities of every species.

Again, the fact that the male in some species and the female in others perform certain functions during the life of their young brood has a most interesting but a somewhat perplexing side. I remember only last summer, just a year ago, finding on the Pacific coast a fish which is well known, I am sure, to Doctor Gill, *Porichthys porissimus*, a very unprepossessing fish in appearance, but a fish which has the peculiar habit of sitting beside its eggs through development; and not only sitting by them and watching them, but singing to them, and as you walk along the beach you hear the peculiar cooing sound, or kind of croaking sound, which the parent fish makes when sitting by her brood and watching them. What the meaning is we can not surmise; but we find the fish singing to its young when they are actually attached firmly to the underside of the rock where the female deposited the eggs. Whether it is the male

or the female that sings I am not able to decide, but I did observe that the young when hatched out remained attached to their place of birth—a very remarkable phenomenon. Instead of hatching and liberating themselves in the water, the young emerge and remain still attached to the stones where the eggs have been attached through their development; and not only are the young thus attached for a considerable time, but they are "oriented;" their heads seem to be all turned the same way. These young, like a little army, all point their heads the same way and point their wiggling tails the other way, a very curious and quaint spectacle.

I say we are doubly indebted to Doctor Gill for bringing his very important observations in a condensed form before us at this time, and I think the congress is with me heartily in saying this.

Dr. Hugh M. Smith (Washington, D. C.). I do not intend to attempt to express my obligations to Doctor Gill for all the encouragement he has given to me and to numerous others with whom I am acquainted, because it would take all the remainder of the session to do that. I simply rise to confirm the statement that Doctor Gill made in regard to oral incubation in certain little fishes, of which I have recently caught a great many in the Philippines. Only a few months ago, while engaged in collecting on a coral reef in the southern part of the Philippine Archipelago, we exploded half a stick of dynamite, and as a result of that one discharge we actually collected 800 specimens, representing nine species of the genus *Apogon*, or *Amia*, as it is now called; and, as far as I was able to see at the time, in each of these species the male fishes had their mouths crammed with eggs. [Applause.]

Dr. Tarleton H. Bean (New York). Just a word with reference to the remarks of Professor Prince concerning the toadfish of the west coast. Professor Prince doubtless is aware, and, I dare say, it has been brought out in this conference, that the reason for the attachment of the young toadfish, *Opsanus*, or *Porichthys*, as the case may be, is the presence of a ventral disk which is similar to the ventral disk of the lump-fishes, but which disappears, in *Opsanus* at least, after the fish has reached the length of about three-quarters of an inch. I have often collected the little fellows, and have been extremely interested in observing how it was that they remained attached, not only to their place of shelter, but to the place at which they derive their first supply of food. [Applause.]

The Acting Chairman (Doctor Gill). Are there any further remarks? If there are no further remarks, I beg to thank the president and the gentlemen for their kindly expressions.

But a few words with reference to the subject at issue. I was very glad to hear Professor Prince make his remarks about the toadfish of Pacific waters, for it tallies very well with the habits of the species of our eastern coast (*Opsanus*). The species, however different externally, are rather closely related; that is, they belong to the same subfamily but to very different genera; and Professor Prince is the first one who has given the details respecting the species of the west coast (*Porichthys*). The habits of our eastern species have been long known. They were described more than a quarter of a century ago by Doctor Ryder, who gave illustrations of the adhesion of the eggs to blocks of wood, and also maintained that the young were attached in the same way during the early condition of life.

HABITS AND LIFE HISTORY OF THE TOADFISH (OPSANUS TAU)

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CONTENTS.

	Page.
Materials and methods of study	1073
General description of adult toadfish	1073
Historical account	1074
Habits and characteristics	1077
Nesting habits	1077
Nesting places	1077
The eggs	1078
Number of eggs in a nest	1081
The fish polygamous	1081
Orientation of the embryos	1082
Care of the nests	1083
Cleaning the nests	1085
Brooding and guarding the young	1086
Attitudes and movements	1087
Feeding habits	1088
Food	1088
Capture of food	1089
Disposition	1089
Feeding in captivity	1090
Fighting tendencies	1091
Diseases	1091
Vitality	1093
Winter habitat	1093
Sounds	1093
Economic value	1094
Life history	1095
Organs of generation	1095
The ovary	1095
The testis	1096
Fertilization and embryonic development	1096
Natural fertilization	1096
Artificial fertilization	1096
Formation of the germ disk	1098
Segmentation	1098
Invagination	1099
Formation of the embryonic shield	1100
Differentiation of the embryo	1100
The larval toadfish	1101
Early stage	1101
Late stage	1103
The free-swimming young toadfish	1105
The adult toadfish	1106
Literature cited	1108

HABITS AND LIFE HISTORY OF THE TOADFISH (OPSANUS TAU).

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MATERIALS AND METHODS OF STUDY.

The material on which this paper is based was collected and the notes were made while the author was a temporary assistant in the United States Fisheries Laboratory at Beaufort, N. C., during the summers of 1906, 1907, and 1908. The collections were made in all parts of the harbor, but the best collecting ground was a shoal lying directly in front of and not farther distant from the south front of the laboratory than 100 yards.

The "nests," consisting of tin cans, empty *Pinna* shells, pieces of board, etc., were brought in in buckets of water and placed in aquariums or in shallow pans under jets of running salt water, or in a large tank 3¾ by 7¾ feet, filled with fresh salt water to a depth of 6 inches. In some of these aquariums there were placed nests with guarding fish; in others nests without any fish; while in the tank there were always numbers of fish, both adults and half grown.

The nests thus placed were perfectly accessible and could be inspected at any hour of the twenty-four. Daily they were taken out, put in shallow pans of water, and minutely examined under a glass. Selected eggs and larvæ were put in killing fluids, careful notes were taken, and at intervals the eggs and nests were photographed.[a]

GENERAL DESCRIPTION OF ADULT TOADFISH.

For a description of this singular fish the writer can not do better than quote Doctor Gill (1907) and Miss Clapp (1899), since their descriptions leave little or nothing to be added. Doctor Gill says:

> They [the toadfishes] have an oblong form, a broad flattish head, restricted lateral gill openings, two dorsal fins, the anterior very small and with only two or three spines, the second very long, the anal moderately long, the pectorals broad, and the ventrals jugular and imperfect (1, 2- or 3-rayed).

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[a] I am under obligations to Mr. Henry D. Aller, Director of the Beaufort Laboratory, for furthering this research in every way possible, and to Dr. H. E. Enders, of Purdue University, for taking the photographs from which some of the figures are made. The other figures are made from photographs taken by myself.

According to Miss Clapp:

> There is something singularly grotesque in the appearance of the toadfish; and, as its name would imply, there is a superficial resemblance to the familiar batrachian. The sluggish disposition, the mottled brown and gray of the wrinkled, scaleless skin, the depressed head and toadish eyes do not suggest the typical teleost. The young fish are tadpole-like in their form and motions. * * * It will be seen that there are quite conspicuous projections of the skin on the head. Besides the paired flaps found in connection with the sense organs, there are other single, often longer projections to be found, which become laciniated in the older fish. These are especially prominent about the mouth, fringing the margin of the lower mandible and opercular regions, while over each eye rises a broad conspicuous flap, giving an owl-like facial expression. * * * The function of these skinny tentacles seems evidently to be for protection, as they strikingly resemble both in color and form the seaweed (*Fucus*) that abounds near their favorite haunts.

Toadfish are somewhat variable in color, but may, generally speaking, be grouped in three classes—those which are a muddy green, those with brown on the upper parts, and those which approximate yellow. I am inclined to think that the former are found largely in deeper water, the latter two classes in shallows. There is, it must be understood, no definite line of demarcation, since all degrees of gradation from class one to two and to three exist. Perhaps the greatest variation, however, is not so much in the ground color as in the markings and blotches which render one fish distinguishable from another. These markings, generally of darker color, are found on the head and fins, particularly the dorsal and caudal. One very large fish of particular marking comes to mind. This was a brown male with an enormous head, the whole right side of which was of a velvety black color, the bright eye with its St. Andrew's cross being near the center. This fish always recalled a bulldog with a black patch covering the right side of the head. It may be added that the toadfish has to a considerable degree the power of changing its color to correspond with the bottom on which it happens to find itself.

HISTORICAL ACCOUNT.

When one considers the abundance in which this fish is found along the Atlantic coast, the large size of the eggs, and the ease with which, owing to the nesting habits of the parents, the eggs can be obtained, one wonders that the embryology and habits of the toadfish have never been worked out. But, excepting two short papers by Ryder, there has been no attempt to study the life history of *Opsanus tau*. There are, however, several papers, long or short, dealing with the habits and with the development of particular organs, which will be referred to later. Since those particular points in the articles cited which touch upon this research are referred to at length in the body of this paper, the references in most cases taking the form of quotations, it will not be necessary here to do more than list the papers and give a general synopsis of their contents.

This fish was first described and named (*Gadus tau*) by Linnæus from a specimen collected by Doctor Garden, of South Carolina. The earliest figures of the toadfish that I have been able to find are in plate LXVII of Bloch's Atlas to his "Oeconomische Naturgeschichte der Fische Deutschlands," published about 1782. These figures, one a dorsal, the other a lateral view, are very good, the latter especially.[a]

The first American describer was Doctor Mitchill (1815), of New York, who allied it with the angler (*Lophius*) because of its large head adorned with skinny tentacles, and its cavernous mouth. His description is an excellent one.

Rafinesque in 1818 describes, under the name of *Opsanus cerapalus*, a toadfish from the south shore of Long Island. This, he notes, is found spawning along the shores during the summer but is not seen in winter. So far as the present writer knows, the first American ichthyologist to figure this fish was Le Sueur. His drawing, published in 1819, represents the fish in the attitude of swimming. This admirably drawn and thoroughly characteristic figure has been reproduced in Doctor Gill's (1907) paper, referred to later.

Le Sueur, following the lead of Mitchill, allies the toadfish, which he calls *Batrachoides vernullas*, to *Lophius*. In another paper the same author (1824), in describing what he thought were two new species of the toadfish, thus justifies the name *Batrachoides* which he first applied to this fish:

> The name *Batrachoides* * * * is a very appropriate one, inasmuch as the form of the body of these fishes has considerable analogy with the larval or imperfect and exclusively aquatic state of the frog; this similarity exists in the large depressed head and wide mouth, the attenuated body edged with an almost continuous fin above and beneath, and, in fact, a general conformity which at once reminds us of the numerous family of Batrachians that are inhabitants of almost every country. This general resemblance is evident to the common observer and they are known by the name of toadfish to the inhabitants of Salem, Rhode Island, and Egg Harbor, and probably also Carolina.[b]

His first specimens were very small, consisting of two individuals of 5½ inches each and one of 2½ inches in length. This latter was taken from a living oyster, in which Le Sueur thinks it had taken refuge in alarm at the noise and motion of the oyster tongs.

In 1842, De Kay, following Cuvier and Valenciennes, gives the name *Batrachus tau* to the toadfish, but still retains it in the family *Lophius*. He

[a] In Marcgrave's (1648) Historiæ Rerum Naturalium Brasiliæ, on page 178, there is figured and described a fish "called Niqui by the Brasilians, and Pietermann by the natives." Both the figure and the description lead me to believe that the fish Marcgrave had was a toadfish. Jordan and Evermann (1898) make no reference to this fish in their description of North American forms. Since, however, in a footnote to page 2315, they refer to certain structures in "the Brazilian genus *Marcgravia cryptocentra*," one may be allowed to conjecture that this is the fish referred to above.

[b] Hargreaves (1904), writing of the pacuma, *Batrachus surinamensis*, of Guiana, says. "The head of the pacuma is exactly like that of a huge toad and has much the same color and markings as the common crapaud."

also describes another fish (1 inch long and undoubtedly the young of the above) as *B. celatus*. This latter he notes is frequently found in oysters, while in 1824 a shower of them fell in the streets of New York. De Kay gives two figures of the toadfish, but they are not to be compared to Le Sueur's splendid drawing. The present writer twice went over the plates of this paper without recognizing either figure as that of the fish in question. One figure has the caudal fin pointed, the other rounded.

Storer (1855) in his "History of the Fishes of Massachusetts," published about the middle of the last century, gives a very interesting but not wholly accurate account of the nesting habits of the toadfish. As the essential points in his paper will be discussed later, it will not be necessary to go further into it here than to say that he was the pioneer worker on the habits of this fish. He obtained his information chiefly from Dr. William O. Ayres, of East Hartford, Conn. This information must have been conveyed by letter, for in Ayres's paper published thirteen years before (1842) there is a very meager account of the general habits only and no reference whatever to the nesting habits. Ayres's paper will be referred to later.

Yarrow (1877), twenty-two years after Storer, in listing the fishes of Beaufort Harbor, speaks of finding a nest of toad eggs in an old boot leg. In 1881, Alexander Agassiz, in the course of an interesting article, "On the Young Stages of Some Osseous Fishes," describes the coloring of a half-grown larva and figures the heterocercal tail. In a popular article published in Harper's Magazine, C. F. Holder (1883) figures a toadfish in a nest amid seaweeds, and falls into the popular error of making the mother the guardian. With regard to the adhesion of the eggs, however, he merely says that the young are enabled to cling to the rocks by their yolk sacs, remaining until bold enough to swim away. Goode (1884), in dealing with the nesting habits and embryology of the toadfish, quotes Storer (1855) at length and gives the accurate and highly interesting observations of Silas Stearns, of Pensacola, Fla., all of which are quoted in detail further on.

In 1886 John A. Ryder published the first of a series of short but highly interesting papers on the habits and embryology of *Opsanus* (or, as it was then called, *Batrachus*) *tau*. These papers followed in rapid succession. The first appeared in 1886 and seems to have been an abstract of the but slightly longer article which appeared in 1887. This latter paper, which he calls a "Preliminary Notice," contains six figures, the first illustrations of toadfish embryos ever published so far as the writer knows. The third, last, and possibly most valuable of these papers is an oral communication to the Philadelphia Academy, on November 4, 1890, on "The Functions and Histology of the Yolk-Sack of the Young Toadfish." The striking points of these papers are all referred to later in the body of this article.

Miss Cornelia Clapp, in 1891, published an interesting paper entitled "Some Points in the Development of the Toadfish (*Batrachus tau*)." In this she figures segmenting blastoderms, illustrates and describes the closure of the blastopore and its relation to the forming embryo, and discusses the relation of the axis of the embryo to the first cleavage plane. She also briefly refers to the nesting habits.

Five years later Miss Clapp presented as a dissertation for the doctor's degree at the University of Chicago a paper entitled "The Lateral Line System of *Batrachus tau*," which was published in the Journal of Morphology, volume XV, 1899 This contained figures of early larvæ and gave an excellent description of the fish and of its nesting habits. In the same year and in the same journal one of Miss Clapp's students, Miss Wallace, published a short but valuable article on "The Germ Ring in the Egg of the Toadfish," reviewing and extending Miss Clapp's work. A third paper on the embryology of this fish appeared the same year. This is a reprint of a lecture delivered by Miss Clapp at the Marine Biological Laboratory at Woods Hole, during the previous summer, on the relation between the first cleavage plane and the axis of the embryo. Those points in all three of these papers which deal with matters pertinent to this research are taken up at length in the other parts of this paper.

The last article, so far as has come to the writer's knowledge, bearing on the habits and life history of this fish is Doctor Gill's (1907) "Life Histories of Toadfishes (Batrachoidids) compared with those of Weevers (Trachinids) and Stargazers (Uranoscopids)." This, as the liberal quotations from it in various parts of this paper show, has been a veritable mine of information to the present writer.

HABITS AND CHARACTERISTICS.

NESTING HABITS.

Nesting places.—The toadfish in accommodating itself to its environment has developed most interesting habits. The eggs are deposited in nests, which in the writer's observation have been old tin cans, a broken jug, floating boards, rotting logs lying more or less horizontally in the water, stones (ballast thrown overboard) with an exposed under surface, but especially the empty shells of a large fan-shaped lammellibranch (*Pinna seminuda*) which abound in the sandy shoals around the laboratory at Beaufort.

Miss Clapp (1899) says that—

> The fish resort in pairs to large stones, especially near low-water mark, and, scooping out a cavity beneath, remain for days in this retreat.

Again she notes that—

> The toadfish of the Eel Pond near the laboratory [at Woods Hole] seem to prefer the débris of civilization to the excavation beneath the rock—for example, tin cans, old boots, broken jugs, etc.

These points had been briefly stated by her in the earlier paper (1891) elsewhere referred to.

Ryder (1886) found that—

> The adult toadfish burrows a cavity under one side of a submerged bowlder and to the solid roof of this cavity the female attaches her ova in a single layer. The eggs are very adhesive and quite large, measuring about one-fifth of an inch in diameter. Like the male catfish, the male toadfish assumes charge of the adherent brood of eggs and remains by them until they are hatched and subsequently become free.

A year later (1887) he writes:

> They (the eggs) are dirty yellow, almost amber colored, and adherent to the surfaces of submerged objects, especially the undersides of bowlders, under which the parent fish seem to clear away the mud and thus form a retreat in which they may spawn. The ova are attached to the roof of the little retreat prepared by the adults, where the eggs are found spread out over an area about as large as one's hand, in a single layer, hardly in contact with each other, and to the number of about 200.

Yarrow (1877), writing of the Beaufort fish, tells, as already referred to, of a nest which was found in an old boot leg. Storer (1855), the first writer, so far as I can find, to describe the nesting habits, found the fish living in eel grass or under stones, to the latter of which eggs, several hundred in number, were found attached in June, July, and August. At Beaufort a more interesting, and for the collector more dangerous, place of abode is in holes dug by the stone crab (*Menippe mercenaria*) in sand flats covered with eel grass (*Zostera marina*). In short, the fish resort for egg laying to any place which is dark and which secures a protected abode to the hatching eggs and guarding parent.

The toadfish of the Pacific coast, *Porichthys notatus*, which ranges from Alaska to Panama, has the habit, according to Greene (1899), of spawning during spring and summer in shallow water. Here "the eggs are cemented in a single layer to the under surfaces of stones, and, * * * the male remains with the brood until the young become free swimming." Hargreaves (1904) states that the pacuma (*Batrachus surinamensis*) of Guiana has the habit of hiding in holes in the mud flats, but the context does not indicate whether for the purpose of egg laying or for the sake of protection.

The eggs.—How the extrusion and fertilization of the eggs take place and how their fixation to the nest is effected I have not been able to ascertain, although considerable numbers of fish of both sexes were kept for months in the large tank (above referred to) well equipped with tin cans, jars, boards, and especially empty *Pinna* shells. The fish readily inhabited these receptacles, but laid no eggs. On one occasion I found in a shell out in the harbor a pair of fish presumably spawning, since there were a few eggs in very early stages adhering to the nest. Though both fish and nest were carefully brought in and placed in the tank, no more eggs were laid.

The egg is permanently oriented with the ventral pole of the yolk fixed to that part of the egg membrane which is fastened to the object acting as a nest. The part of the eggshell there attached is not, as Miss Clapp (1899–1899a) indicates, always opposite the micropyle, but generally so. So far as my observations go, in the great majority of cases the micropyle is opposite the point of attachment, but it may vary within a zone bounded by a circle about 30° away from the animal pole. The blastoderm, and consequently the embryo, as pointed out by Ryder (1886 and 1887) and Miss Clapp (1891 and 1899a), are at the animal pole opposite the point of attachment, though here we find the same variation as is noted for the position of the micropyle.

Just here it is worth while to correct an error into which nearly all those who have described this fish and its young have fallen. Storer (1855), more than a half century ago, in describing the habits of the toadfish, says:

> We may see the eggs, not larger than very small shot; a little later they are increased in size, and the young fish are plainly visible through their walls; a little later still the young have made their escape (i. e., have burst their eggshells), but are still attached to the stone. The attachment now, however, is accomplished in a different manner. The yolk, not being yet absorbed, occupies a rounded sac protruding by a narrow orifice from the abdomen, and the part of the sac near its outer border, being constricted, leaves external to it a disk, by means of which, acting as a sucker, the young fish adheres so firmly as to occasion difficulty in detaching it.

The error here occurs in the idea that there is any "sucker" at the basal portion of the yolk stalk. The egg is simply glued to its support in a manner to be explained presently. It should, however, be stated that Storer did not get his information at first hand, but expressly credits it to Dr. William O. Ayres, of East Hartford, Conn. This, as previously stated, must have been communicated orally or by letter, since it is not found in Ayres's paper (1842).

Jordan and Evermann (1898), in their great work, "The Fishes of North and Middle America," fall into the same error in describing "the young clinging to the rocks by a ventral sucking disk." And Jordan (1905), in his "Guide to the Study of Fishes" speaks of "the young clinging to stones by a sucking disk on the belly, a structure which is early lost." And, last in point of time, Smith (1907), in his "Fishes of North Carolina," says that "for some time after hatching the young remain attached by means of a special sucking disk."

Ryder (1886) was the first to call attention to this error and to explain that the attachment was due to an adhesion of the eggshell to the nest. Later (1887) he correctly describes and figures the eggs as attached by means of an "adhesive membrane," but does not refer to the origin of this. In 1890 Ryder quotes Jordan and Gilbert as to this voluntary adhesion of the young, expressly corrects their error, and goes on to show definitely how the eggs adhere to the membrane and how the membrane is glued to the nest. Miss Clapp, in the three

papers previously referred to (1891, 1899, and 1899a), also refutes this error. In her first paper (1891) she says:

The adhesive disk * * * is about 3 millimeters in diameter. It is a transparent thickening on one pole of the egg membrane, at the time of oviposition, and by means of it the egg is glued firmly to the rock.

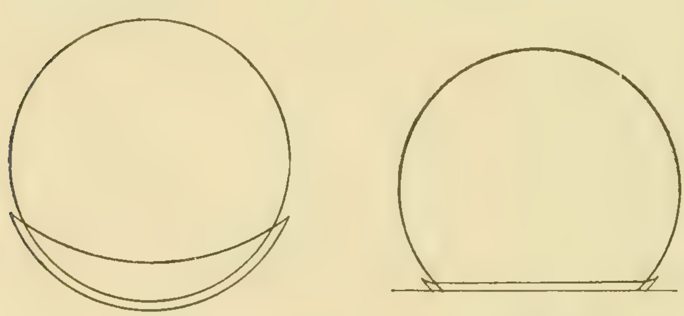
Later she writes more explicitly (1899):

The young fish do not attach themselves by a ventral disk which soon disappears, as has been supposed, but at the time of oviposition each egg is securely glued to the rock by means of a secretion on the membrane at the pole of the egg opposite the micropyle. After hatching, the embryo fishes still remain attached to the rock by the adhesion of the yolk sac to the inside of the egg membrane over the disk area until the yolk material has been entirely absorbed, a period of three or four weeks.

Again, she says (Clapp, 1899a):

The membrane of the egg has a peculiar adhesive disk, about 3 millimeters in diameter, which has a constant position, with the center of the disk at the vegetative pole, directly (?) opposite the micropyle. By means of this disk the egg is firmly glued to the supporting surface. * * * The disk consists of a transparent secretion, which becomes opaque and gluey on contact with water. It is of nearly uniform thickness, and is closely applied to the egg membrane everywhere, except for a narrow margin which projects all around as a thin rim. The disk is saucer shaped and only a little thicker than the egg membrane itself. I have been able to separate it from the membrane in the case of eggs hardened before attachment. As the egg is generally fastened to more or less plane surfaces, it appears strongly flattened on the side of attachment, as described by Doctor Ryder and as shown in figure 3.

This is correct, and Miss Clapp has been quoted at some length in order to give her the credit for discovering the disk and for refuting the errors above noted, and because her clear statement of the facts could not be improved on by me. I am pleased to say, however, that on June 22, 1908, I ascertained that the adhesive disk is to be found in place opposite the micropyle in ripe ovarian eggs when these are allowed to flow from the ovary into water, thus confirming Miss Clapp's statement (1891) that the disk is present at the time of oviposition. When the egg becomes fixed to some supporting body both the disk and the egg become very much flattened on the supporting side. The accompanying text figure[a] shows both these points clearly. *A* is a ripe egg



A B

Diagram (after Miss Clapp) showing adhesive disk of toadfish egg. *A*, before, *B*, after attachment. (Much enlarged.)

[a] Copied from Miss Clapp (1899a). This is the "figure 3" referred to in the quotation above.

fresh from the ovary; *B* is the same after attachment. This attaching disk persists not only while the eggshell is intact but throughout larval life, until the yolk sac has been absorbed and until the little toad breaks away from the nest, leaves the disk behind, and takes up a free and independent life. This, however, will be referred to later.

Number of eggs in a nest.—The number of eggs found in nests varies within wide limits, these being from but few more than a score to several hundred, the numbers generally varying toward the upper limit. The smallest number which I have recorded is 22 in a *Pinna* shell, while the larger and more typical numbers are 181, 340, 361 in *Pinna* shells; 301 in another, 144 eggs on the right, 157 on the left valve; 624 in another shell, 381 being attached to the right valve and 243 to the left; 373 in an empty can; while on a piece of board 5 by 11 inches the amazing number of 723 was found. These are careful counts. On the under side of logs at the island elsewhere referred to two of us estimated that there were 350, 500, and 700 eggs in three nests, respectively. Other numbers might be given, but these are typical.

Where such large numbers of eggs as noted above are found, there is always more or less crowding. On a board, as elsewhere described, 723 eggs were counted in a space 5 by 11 inches. These eggs were very much jammed, some having the vertical diameter twice as great as the horizontal, and in some cases the eggs were piled up on top of each other like large shot stacked up two deep, and were adherent to each other instead of to the board. Figure 5, plate CIX, is a photograph of the board showing this crowding of the eggs. Here my observations are in direct contradiction to those of Ryder (1886 and 1887), who says "the female attaches her ova in a single layer," and again, "the eggs are found spread out over an area about as large as one's hand in a single layer, hardly in contact with each other, and to the number of about 200."

The fish polygamous.—By finding such large numbers of eggs and by noting the comparatively small size of the ovary of the adult females, I am led to conclude that several females have taken part in the laying of such enormous numbers of eggs. Figure 1, plate CVII, is a photograph (normal size) of the ovary of a female 9½ inches long. When we recall that the eggs average 5 millimeters ($^1/_5$ inch) in diameter, we arrive at the conclusion that one fish can at the most lay hardly more than 100 eggs. It is well known that domestic fowls lay many together in one common nest, and so it is with the toadfish. A fact that tends to confirm the matter is that eggs in nests are frequently found in two or three different stages of development, often rather near each other in time, but frequently as much as two or three days apart. For example, in a *Pinna* shell brought in on July 19, 1906, each valve had eggs in two stages. On the right valve 50 and on the left 88 eggs had embryos with the outline of the head just beginning to appear, while 183 eggs on the right and 60 on the left had embryos

with black eyes and free tails. Instances of two or three stages in the eggs of a nest might be multiplied, but the general statement may be made that when such large numbers of eggs are found in a nest they are in more than one stage of development and have been laid by more than one female.

Orientation of the embryos.—Ryder stated (1887) that—

> The young adherent embryos are found tohave their heads directed toward the opening of their retreat and their tails toward its blind and dark extremity. This appears to be invariably the case, and it would seem that the direction from which the light comes, in this instance, at least, has a great deal to do in determining the direction of the axis of the body of the future embryo. This position of the young fishes is maintained as long as they are attached.

The last of these statements is correct, but the others are erroneous. In scores of nests which the writer has examined the embryos are found pointing in all directions. This is especially so in nests which are equally lighted from all sides, i. e., the board nest mentioned above. In a nest on the under side of a log projecting from a bank, eggs were found with the embryos pointing in all directions, but the majority had their heads turned more or less toward the point of greatest illumination. In *Pinna* shells, as shown in figure 7, plate CX, the embryos are almost always turned away from the opening of the shell toward the hinge. The writer is in position to state that only in a very general sense is it true that the embryos have any definite direction of axis, and not "invariably," as stated by Ryder. Figures 9 and 10, plate CXI, photographs of different nests, show this. Pieces of wood, 1 by 2 inches, from the log above mentioned have embryos pointing in as many as nine different directions. In her earliest paper (1891), Miss Clapp quotes Ryder, and adds:

> It was observed during the past summer that the embryos *within the egg membrane* do not have their heads all turned the same way, but in every possible direction, and it is only after the young toadfish are hatched that the heads of the whole brood are turned in the same direction.

That this latter statement is incorrect a glance at figures 7, 8, 9, 10, and 11, plates CX, CXI, and CXII, will show. Smith (1885), in the paper previously referred to, says on this subject:

> In the species of *Lepadogaster* the embryos show a marked irregularity of position; that is, the eggs are affixed to their station regardless of the future growth, which may develop with its head or tail in any direction with reference to the place of attachment.

In a paper published in 1890, Ryder, basing his argument on his (incomplete and erroneous) observations that all the embryos of a brood conform in direction to one axial plane, the heads pointing toward the light, declares that the polarity of the young is determined while the eggs are still in the ovisac of the mother. That this is not true the experimental work of Miss Clapp, as set forth in her papers of 1891 and 1899a, proves absolutely. If further evidence is needed, the reader is referred to the various photographs in this paper in which embryos early and late are shown.

Miss Clapp falls into error, however, in the first of the two papers to which reference is made where, in the passage above quoted, she states that "it is only after the young toadfish are hatched that the heads of the whole brood are turned in the same direction." During the larval period the yolk sac is attached to the inside of the egg membrane, and the possibility is suggested that the turning toward the light is effected at the time of hatching, when, according to Doctor Ryder, the attachment of the yolk sac may take place. In the second of the two papers above noted, Miss Clapp herself records the fact that the egg becomes attached at once to the egg membrane, hence such rotation is an impossibility.

Care of the nests.—When the place for the nest has been chosen and properly cleaned and the eggs laid and fertilized, the female departs, leaving to the male the sole care of the eggs and future young.

Storer (1855), quoting Ayres, says that it is the female which guards the nest. His statement is:

> That this is, in all cases, the mother of the young ones, and that she is there for the purpose of guarding them, we have no means of determining; we can only infer it.

On reading this one is led to wonder why he did not take a pair of scissors and by dissection ascertain the sex. Ryder (1886 and 1887), however, declares that—

> It is the male which assumes the care of the brood, and *seems* [italics mine] to remain in the vicinity until the young fish are hatched out and set free.

Miss Clapp (1899) confirms Ryder, and the writer can testify from scores of dissections that the guardian fish is always and only the male.

For the next few weeks the male gives himself up wholly, so far as the writer has been able to ascertain, to this parental duty. He leaves the nest, if at all, only to feed; and the strong probability is that he never absents himself during the period of incubation, getting the small amount of food necessary during this self-enforced period of inactivity by snapping up unwary minnows and crabs passing his retreat. In support of these conclusions the following facts are adduced:

While the males caught in the traps (to be described later) or found free in the water were always fat and well fed, those from nests, with the marked exception of one lot from a particular spot to which special attention will be called further on, while never emaciated nor showing signs of starvation, were not so well fed as the others. So much as to feeding while guarding nests. With regard to their not leaving the nests, the writer can affirm that he has never yet found a nest with eggs without a guarding male. The fish ordinarily resist being evicted from empty shells, but if the shells are occupied as nests with eggs, then the fish have literally to be driven out. The following incident

is typical. A *Pinna* shell nest, with valves partly open, containing a guarding male, was turned upside down and the fish "poured out" twice. The first time he came out head foremost, but braced his pectorals against the valves so as to be dislodged with difficulty. The second time he appeared tail first, but catching again by his fins and, the shell being partly in the water, swimming with his tail, he actually tried to climb back into the shell. So vigorous is the resistance offered that not infrequently many of the eggs are ruined in getting the guardian out. I recall one particularly desirable lot of eggs in early segmentation in which over 50 had been crushed. My negro collector, when asked the cause, gave the explanation above.

One more illustration is so interesting that it can not be omitted. On one occasion I visited an oyster reef which was about a foot out of water at low tide. On this were many old broken-down piles which had once formed a part of a fish house. Beneath these the fish had excavated retreats, and to the under sides were attached larvæ and unhatched eggs. As the tide fell lower and lower the water in the little pools around these "chunks" seeped out through the sand and shells, but in the score of nests examined not a single one had been deserted. In some cases there were no signs of fish, nest, or water until the "chunk" was turned over. At extraordinarily low spring tides the fish must have been left for a short time with practically no more water than enough to moisten the under side of the body, but in no case was a deserted nest found. The writer has never seen a more marked case of devotion to its young on the part of any fish.

This guardianship, as has been stated, lasts until the young are not only freed from their place of attachment, but are able to fend for themselves. I have not infrequently found nests with young showing no trace of attachment of the yolk-stalk—i. e., with this completely absorbed into the belly—which were still attended by the male, who guarded them as devotedly as ever.[a]

At what age the fish become sexually mature I can not say, but not infrequently empty shells were found inhabited by fish from 2 to 9 inches long (averaging about 6 inches). At least one 6-inch specimen was a "ripe" male, while another, 5½ inches long, proved on dissection to be a female with ovaries filled with eggs of fairly large size. As no attempt to escape was made on the part of these fish, it seems probable that the shell-dwelling habit is formed early.

There has been neither time nor opportunity in the course of this research for the writer to go into any particular study of the extensive literature of nest building by fishes, but the following interesting account has come to notice and is in all ways so parallel to that given for the toadfish that it is worth repro-

[a] There is at Beaufort a blenny which lays its eggs in shells and guards them. One dissection showed that the guardian was a male.

ducing. William Anderson Smith (1885), writing of the British suckerfish (*Lepadogaster*), says that *L. decandolii* deposits its eggs under stones and that these are watched by the parents. Of another species he writes:

I have scarcely ever taken the ova of *L. bimaculatus* except arranged in regular rows in the empty shells of scallops (*Pecten opercularis*).

The eggs are generally accompanied by the parent, curled up inside of the shell watching the progress of her progeny [the context does not indicate that the sex was determined by dissection]; and if the dredge should bring up a shell thus supplied with ova from 8 to 12 fathoms off the scallop ground, if the fish is not in the shell it is almost sure to be in the other contents of the dredge, showing that it had either come out in the capture or been watching close by.

Cleaning the nests.—Connected with the manner of feeding, an interesting thing has been noted. If bits of food put in a *Pinna* shell occupied by a toad were not eaten, the fish would take them in his mouth and "blow" them out some distance from the shell.[a] This is one way in which the nests are kept clean. Another is by the action of the pectoral and caudal fins in "fanning out" all small particles. All nests in the harbor, even in muddy water, are perfectly clean and free from sediment, as well as larger nonfixed particles.

A bit of experimental evidence may properly be adduced here. Aquariums or pans containing shells with eggs were put under running salt water. Fish were put into some (they readily adopt nests other than their own) but not into others. The eggs in aquariums with fish were invariably freer from sediment and made better progress than those which had no guardians. The fanning action could not operate at the bottom of jars 8 inches deep, and so another explanation has to be sought for. Having observed that these fish give off large quantities of mucus which sometimes comes to the surface in visible masses, I have arrived at the conclusion that this mucus entangles the sediment and thus carries it off. Let the explanation be what it may, the facts are that nests with guardian fishes were always cleaner, the eggs showed fewer losses and developed better than those without care takers.

Perhaps it was this same instinct on the part of the fish, of getting rid of all débris, that led to a very curious action which may properly be related here. On July 30, 1906, one of two fish, in an aquarium measuring 8 by 10 inches, picked up in his mouth a sand dollar 4½ inches in diameter, rose to the surface, and tried to throw it out. As the water filled the aquarium to the brim, he would have been successful had not the iron rim by projecting inward one-fourth of an inch prevented. He persisted in his attempts, however, making six or eight trials in the course of two hours. On August 1 the same fish tried the same thing over and over again.

[a] It may be remarked in passing that the fish will not infrequently blow out the food to take it in again. From repeated observations, I am led to conclude that, since this generally takes place with pieces of fish, the toad is simply trying to get them endwise for easier swallowing.

Brooding and guarding the young.—Intimately connected with the foregoing is a habit which I have noticed repeatedly in this fish and which from its likeness to a similar action on the part of the hen may for want of a better term be called "brooding." The following incidents are transcribed almost literally from notes made at the time.

On July 9, 1907, a number of little fish detached themselves from a nest, in this instance a piece of board. At 11 p. m. the male in the aquarium with them was lying on the board and with spread-out pectorals was brooding the young which hovered under these fins and under his body. When I put in my hand he threatened to bite. On July 13 this board with a number of larvæ still adherent and with a good many free little fishes hidden in holes made by the shipworm, *Teredo navalis*, was removed for examination, whereupon the male stood up on his jugularly placed pelvic fins in a manner familiar in the blennies and young of the sea bass (*Centropristes striatus*), and looked searchingly around, the free young left behind playing under him and between his pelvic fins. On the following day, when the board with the young was again taken out, the adult again went through the same performance, but became perfectly quiet when the board was put back. On the succeeding day, when the board was taken out, the fish tried to bite me. Then he stood on his pelvic fins and literally glared at me with mouth open and teeth showing in a very vicious manner. At this time the toadlets were collected mainly under him and between his pelvics; some, however, were on his head, and one swam into his mouth and then out again.

The nesting habits of this fish and the fixation of the ova are undoubtedly brought about by the great size of the eggs. If these huge eggs were set free in the water, by virtue of their lack of any buoyant apparatus, they would at once sink to the bottom, where, because of their large size and striking (yellow) color, they would attract enemies without number. Further they must adhere to these nests, since the nests are found in shallow water where waves and tides, acting freely on them, would, because of their great bulk, if they were not attached, quickly carry the eggs out of the nest, and so they would be lost.

Correlated with this large size and fixed condition of the ova and larvæ are the large size and great activity of the young when set free. The salmon egg is about the same size as that of the toadfish, but the salmon larva when set free is burdened with a great mass of yolk, which hampers its movements and makes it an easy and attractive prey to its enemies. The little toadfish when detached differs from its parents in magnitude only, and by reason of its large size, finished body, and great activity, can at once begin an independent life.

Silas Stearns's observations (quoted by Goode, 1884) go further than the writer's in the matter of the fishes guarding the young. They are so interesting and circumstantial that they are given here.

When its young have been hatched, the older fish seems to guard them, and teach them the devices of securing food in much the same manner as a hen does her chickens. I have spent hours in watching their movements at this time, and was at first much surprised by the sagacity and patience displayed by the parent fish.

ATTITUDES AND MOVEMENTS.

In 1906, attitudes of standing on pelvic fins were seen to be assumed by fish which were not guarding nests. The fish previously referred to as trying to rid its aquarium of a sand dollar repeatedly postured in this fashion. At a little later date a number of fish assumed the same attitude. Again a large fish (not one of the above) not only stood up on his pelvics, but deliberately yawned, gaping his mouth widely. In the earlier instances cited, the taking of this attitude seems to have been in anger at the removal of the nest and for the better protection of the young by admitting them under the body; in the last case it was probably assumed as a part of the yawning action of the fish. (That fish yawn, the writer can testify from repeated observations; even larvæ with still adherent yolk sacs do so.) For the other instances no explanation is at hand.

Other curious attitudes also were assumed by the fish. One fish in a round aquarium was seen to lie for two hours on his side with his belly against the glass. On the next day the same fish stood on his tail between a large bottle and the wall of the aquarium, and, with his belly against the glass and his mouth nearly closed, breathed through the right gills only. This continued for some hours. The closest scrutiny could detect no motion whatever of the left operculum. This fish and his companions were quite tame and were handled with ease and safety. On the next day both stood on their tails, bellies to the glass, heads laid back, and gill covers barely moving. One of these fish (recognized by a spot on his dorsal) was the one whose yawning has just been described.

Again, two other fish in another aquarium, seven days later, stood vertically, resting on the roots of their caudal fins, clinging to the glass by the fleshy parts of their jugularly placed pelvics. Later, one of these stood on his tail (bent about midway between anus and caudal), and touched the glass with the barbels of his lower jaw only, occasionally moving his pectorals gently. Again, one of these two, some days later, stood vertically clinging with pelvics to the glass, with his caudal fin gently sweeping the floor of the aquarium. Many of the fish were given to lying with the caudal bent abruptly upward at an angle of at least 45 degrees. As to why these attitudes are assumed, the writer has no conjectures to offer.

I have seen a fish crawl into a tin can, seemingly only large enough for his head, and then turn around until both head and tail projected from the opening, the tail perhaps partly covering the head. The fish were fond of crawling into shells or empty Mason jars and then reversing ends until only the head was visible.

Sometimes they would back in until only the head remained uncovered. Storer (1855), probably quoting from Ayres, describes this attitude well. He says:

> If we approach this (cavity) cautiously, we shall probably distinguish the head of the toadfish very much in the position of that of a dog as he lies looking out of his kennel.

In nature the fish are solitary rather than social in habits, but in the aquarium they herd together and lie heads on each other like a lot of pigs. Gill (1907) has well described this habit, and I can not do better than quote him, as follows:

> Where many are together, they may congregate in a heap in some retired nook. The crowding together of many individuals just alluded to is a characteristic habit in aquaria at least. The toadfish is not a schooling or social animal as generally understood, but there are very few others who will associate as closely as it does. All the fishes in a toadfish aquarium may occasionally be found massed together in a regular heap, as close together as possible, in some selected corner, some on top of others. In such positions some may remain quite a long time (perhaps an hour even) and most of them scarcely move; there will be often some restlessness, nevertheless, and from time to time one or more may leave and swim about or possibly seek another corner.

This description is as accurate as a photograph.

Doctor Gill further writes:

> When at rest its attitude is quite characteristic; its head is somewhat tilted, sometimes supported by a stone, a sloping decline of sand or mud, or, it may be, on the body of a companion. The fins, unlike those of most fishes, are often maintained erect, the first as well as the second dorsal being completely upraised, while the caudal may be almost folded; the pectorals are near the sides, but with the lower edges everted and borne on the ground; a slow movement of inspiration and expiration is kept up, the jaws being very slightly open and moved, and the gill membranes slightly puffing and collapsing in harmony; otherwise the fish is motionless. Different individuals, however, may assume very diversiform attitudes, and some coil themselves up so that the tail touches the gills or, maybe, is tucked under a pectoral fin.

All of these attitudes I have seen scores of times.

To a very slight degree the toadfish moves by crawling, using its jugularly placed pelvic fins for this purpose. It may swim, using either pectorals or caudal, or both. When using the pectorals only, the caudal is held still and the motion is slow. The most common mode of progression is by the use of the caudal, helped by the long dorsal. With each right or left stroke of the tail an undulatory movement is set up in the dorsal, which aids materially in propelling the fish forward. This gives the whole body a wriggling motion, as is well portrayed in Le Sueur's (1819) figure, reproduced on page 394 in Doctor Gill's (1907) article.

FEEDING HABITS.

Food.—The toadfish is omnivorous; "all is grist that comes to his mill." But the pièce de résistance of his daily fare is crab, young molting blue crab preferred; any crustacean will do, however, or fish, or almost any kind of offal.

In 1907 a fish trap was hung off the wharf and kept baited for toadfish. There were caught, almost daily, numbers with bellies enormously distended with fish swallowed while in the trap. On being put into the tank the toads disgorged pieces of fish of such large size that one wondered how they could have been swallowed. One giant toad had his belly swollen balloon-fashion to such an extent that for two or three days his tail parts floated high in the water (nor could he get them down) while his nose rubbed the floor of the tank. He finally, however, got rid of both food and gas and seemed to be none the worse for his experience.

On the trip to the oyster rock holding the old log remains of a fish house, elsewhere referred to, large numbers of toads (about 25) were found under the rotting logs partly imbedded in the sand and shells. These fish all had distended abdomens, leading me to hope that some of them at least were ripe females; but under pressure they gave out blue crab remains either at one end or the other. Those that were brought in and dissected proved to be males, the distension in all cases being due to crabs. These were the only guardians I have ever found that were particularly distended with food. That they were so well fed is doubtless due to the fact that as the water receded the crabs sought shelter under the very logs which concealed the toadfish, their worst enemies.

Capture of food.—As to the manner in which the toadfish catches its prey, Silas Stearn's description, as quoted by Goode (1884), is so accurate as to leave nothing to be added:

> It secures its food rather by strategy and stealth than by swiftness of motion. Hiding under or behind stones, rocks, or weeds, or stealing from one cover to another, it watches its victims until the latter are near by, when it darts forth with a quickness quite astonishing, considering its usual sluggishness, and back again to its hiding place, having one or more fish in its stomach and on the alert for others.

Linton (1901) notes that its alimentary canal is chiefly filled with crustacean and molluscan remains and the bones and scales of fishes.

The mouth of the toadfish is eminently fitted for the catching and reception of the kind of food described above. The buccal cavity is enormous, as might be inferred from the size of the great, broad, blunt head. The gape of the mouth is very large and the powerful jaws are filled with bluntly conical teeth (as first noted by De Kay (1842) and later (1855) by Storer) with which the fish can inflict a rather severe and painful bite. Incidents to illustrate the action and utility of the mouth and jaws appear in the following paragraphs.

Disposition.—The toadfish is commonly credited with having a savage and even vicious disposition, an impression which is to some extent due to its unprepossessing appearance. After a somewhat intimate acquaintance with more than 100 individuals, however, I find that, like other animals, some are of good

disposition and some of bad, and, moreover, that given individuals are even subject to moods, as incidents related below will show.

Toadfishes that have been teased always snap viciously at everything near them which moves. A 9-inch specimen after such treatment clinched his teeth so tightly on a bit of oyster shell that he was by it lifted out of the water and into a bucket. Ayres (1842) records a similar experience in the following words:

> One which I caught the last summer and kept for some time would snap fiercely at the finger or a stick held toward him and would sometimes allow himself to be lifted out of the water before he would loose his hold.

I have several times been bitten by these fish so that the blood came slightly; but the teeth are not sharp enough to draw blood ordinarily. Toadfish never hold on when they bite, but snap and let go. Though very sluggish, in biting they move faster than the hand and almost faster than the eye.

Some of the toadfish always remained vicious, others, after being in captivity awhile and fed by hand, became quite tame, some so much so that I could handle them with impunity. Those guarding the nests were more apt to bite than the nonguardians. If the nest, e. g., the shell with the affixed eggs, was taken from the aquarium, the fish was apt to become restless, and if the hand was put in the aquarium, he was likely to snap viciously at it. I have a note of a particular case in which this happened, but immediately thereafter the fish let himself be taken up in the naked hand and transferred to another aquarium. Another fish kept for some time in a tank 3¾ by 7¾ feet became so tame that he allowed me to handle him freely, to carry him in my naked hands to the camera 40 feet away, and to adjust him under it.

While these examples are specimens of the conduct of the fish in general, it is necessary to say that some were vicious, always snapped if they got a chance, and if not, always showed their teeth ready to bite if one came near. Goode (1884) formed a very favorable opinion of the fish, for he says:

> Although it is armed with by no means insignificant spines, which are capable of inflicting serious cuts, when touched they show no disposition to bite, but erect their opercular spines in a very threatening manner.

Feeding in captivity.—Nowhere do the varying dispositions of these fish show more plainly than when they are being fed. Considerable numbers of them were kept, and it was necessary to feed them when one could, for, in captivity, because of their inactivity, they mostly feed sparingly and at irregular intervals. Some, however, fed eagerly, swimming out from their retreats when oysters or bits of fish were thrown into the tank. For those not so tame a different method had to be pursued or some would probably have starved. These would snap a piece of fish held before their mouths in a pair of forceps. Some, however, could only be induced to eat by rapping them over the nose with the

forceps, at which they would snap and take the oyster or piece of fish. One fish, after several days of this kind of experience, would gently close his mouth on the end of the forceps and pull the meat off, or finding none there would (especially if his head had been stroked or tickled with the forceps) close his mouth gently and let go without manifesting irritation.

To sum up the whole matter, my experience is that even such vicious fish, as many of these are, can in the majority of cases be tamed, if they are not teased or otherwise unnecessarily disturbed, if they are fed regularly and by the same person, and if they are not handled roughly and punished when they bite. Further, confinement and hunger are factors which must play a great part in taming fish. Fish guarding shells with eggs are much more likely to bite than those in empty shells, even though ordinarily they may be handled with impunity.

Fighting tendencies.—The toads are very much given to fighting among themselves. On one occasion a big fellow twice tried to swallow one slightly smaller than himself, and had gotten him down as far as back of the eyes, when by catching each by the tail I separated them. After the second separation they remained quiet, the smaller seeming not much worse for the experience. Six days later my attention was attracted by a great commotion in the tank, and I found that a large fish had clinched a smaller one as above described, and so determined was he that he let go only when struck repeatedly on the head with a piece of iron pipe. These were presumably the same pair as the above. Linton (1901) records a similar occurrence as follows:

> I have seen a toadfish in the aquarium in the act of swallowing another of its own species but little smaller than itself.

He also notes finding a partly digested toadfish in the stomach of another.

Just in proportion as the fish were well fed their propensities for fighting increased. During the first week in July, 1907, quite a number were in the large tank elsewhere referred to and were a lively lot. They were especially active at night after the lights were out and the laboratory was deserted. On coming in late at night, not infrequently a tremendous splashing could be heard, and, on striking a light, the fish could be seen fighting all over the tank. Morning after morning the floor around the tank would be wet with water thrown out in their struggles. So far as observations went, there was no attempting to swallow, but simply clinching and breaking away. This was again noted the last week in the same month.

DISEASES.

So far as the writer has been able to ascertain, the toadfish, because of his retiring manner of life, has both few enemies and few diseases. The latter are

chiefly due to parasitic worms, entozoa. From their omnivorous habits the fish are especially subject to these. About 40 per cent of the 48 examined by Professor Binford in 1908 were infected with *Ascaris*. Linton (1905) in his "Parasites of the Fishes of Beaufort" reports the examination of 135 toadfish. From these he obtained more than 190 nematodes, about the same number of cestodes, and more than 100 trematodes. The nematodes are all of one species (*Ascaris habena*), the cestodes of five genera and as many species, and the trematodes (so far as identified) of three genera and three species. Examination of Linton's other publications will show that toadfish in other localities are similarly infested.

In the course of this research it was not infrequently noticed that some of the toadfish kept in confinement had "pop-eye." Whether these fish were thus affected when captured, or whether the trouble originated in confinement, can not be stated, but it should be noted that other fish, kept in the same tank at the same time, and large numbers of various kinds of fishes kept in running water under the writer's care during the five preceding summers, showed no symptoms of this disease.

Direct evidence is at hand, also, to show that wild fish have the same trouble. On July 7, 1907, there was taken in the trap hung off the wharf a large toad which had either the conjunctiva or cornea [a] of its eyes enormously distended, projecting one-half to five-eighths inch in front of the iris. One other fish caught at the same time showed a slight distension of the eye covering, while others had eyes perfectly normal in this respect. Pressure applied by means of a pencil to the eye showed that whatever caused the distension gave the membrane great firmness. Neither the distension nor the pressure of the pencil seemed to cause the fish discomfort, for only after an appreciable length of time did he move away, and then in an undisturbed manner. This was not that form of exopthalmia in which the whole eye is pushed out of the socket. The distending substance was evidently between the eye proper and its outer covering.

On July 10, 1907, two fish were taken from the trap at the wharf. Both these had their caudal fins blood red in those parts where the pigment was not so dense. Whether or not this indicates disease the writer can not say, but it is not an altogether uncommon phenomena among fishes, as he has noticed it in other forms, *Lepisosteus*, for example. At the time it was thought that maybe it indicated sexual maturity, as noted in *Lepidosiren* by Kerr (1900), and dissection showed that one, a male, was breeding, while the other, a female, had eggs nearly ripe enough to flow from the ovary.

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[a] I unfortunately did not dissect to ascertain which.

VITALITY.

The vitality of toadfish is extraordinary, almost equal to that of the Reptilia. Incidents might be multiplied, but two will be sufficient to make clear this assertion. Before dissecting them it was my custom first to cut through backbone and spinal cord back of the head, and sometimes in addition to "pith" them. On June 28, 1907, this double operation was performed on a number of fish, which nevertheless during the operation and afterwards opened and closed their mouths, erecting their spinous dorsals, expanded their pectorals, and gave forth the curious sound made by the air bladder, which may be most nearly rendered "oonk" or "koonk.". This sound was made by one or more fish while the air bladder was being removed.

While the above paragraph was being written, a toadfish whose spinal cord had been cut, whose belly had been ripped up, and whose stomach had been opened, was brought to me. It was put in a dry dish and set aside. When opportunity offered, some three or four hours later, I took it up and began examining its mouth to get the exact shape of its teeth; whereupon it snapped at my fingers half a dozen times. Goode (1884) remarks on this subject:

> They are very hardy, and when taken from the water will lie for many hours, and soon recover their ordinary activity when restored to the water.

Ayres (1842) had one live for twenty-four hours without water after it had been taken with the spear.

WINTER HABITAT.

What becomes of the toadfish during the winter the writer can not say. According to Ayres (1842) they go into deeper water, bury themselves in the mud, and remain in a torpid condition until spring. Goode (1884) says:

> The bottom temperature of the water frequented by these fish would appear to range from 50° F. to 90° F. In the more northern regions throughout which they are distributed they appear to become torpid or nearly so in winter, and it is stated by Storer (1855) that they are frequently found in the mud by men spearing eels.

SOUNDS.

As indicated in the paragraph on vitality, the toadfish makes a definite sound which may be fairly rendered verbally by "oonk" or "koonk." These sounds are produced by the contraction and relaxation of muscles connected with the air bladder, which has been figured and its structure described by Sörensen (1884). This paper the writer has not had an opportunity of consulting, but Doctor Gill (1907) reproduces the figure and translates from Sörensen, as follows. (The air bladder is small, U-shaped, and hence nearly doubled, the paired limbs of the U projecting anteriorly.)

Above, the division extends backward half as far again as on the underside. The inner surface of the air bladder presents no projecting membranous partitions or the like. The outer membrane is strong, tough, fibrous, and rigid; the inner somewhat thicker than usual. On the sides of the air bladder are found a couple of large muscular bands, especially thick behind, which cover more than half the surface of the organ. On the underside they do not extend as far toward the middle as on the upper surface, where they meet behind. The muscular fibers run transversely but at the same time somewhat obliquely backward (on the ventral side beginning at the middle, on the upper side toward the middle); toward the hinder end of the organ the fibers gradually run transversely. The pleura is strong, but rather thin; it is, however, thicker on the back side, where the muscle bands meet.

With this air bladder the fish is enabled to make the sound above noted, and which is variously rendered as "oonk," "koonk;" or "ung," "kung." The note or sound is always given twice, "koonk-koonk." The fish in the laboratory rarely make this sound, which has considerable carrying power, save at night or when caught and carried about (generally wrapped in a towel for precaution's sake).

ECONOMIC VALUE.

Those who have eaten this fish pronounce the flesh not unpalatable. Rafinesque (1818) says that the fishermen "don't reckon it good to eat, and often throw it away on the beach, yet it is as good as the different species of Phycis or Cusk." De Kay (1842) affirms that it "finds no favor with the fishermen, on account of its unsightly appearance; its flesh, however, when properly cooked, is well flavored."

Storer (1855) writes on this subject as follows:

> The toadfish is not commonly employed as an article of food. Its generally repulsive aspect causes it to be looked upon rather with disgust. That its flesh is delicate and good, however, can scarcely be questioned, though the small size which it attains and the fact that it is never taken in any large quantities prevents it from being of any economic value.

Goode (1884) took a more optimistic view of the commercial possibilities of this fish. He writes:

> The toadfish may be regarded as constituting one of the undeveloped resources of our waters, and it can scarcely be questioned that in future years it will be considered as much more important than at present. No estimates can be given as to the quantity now yearly entering into consumption, and, since it is almost never offered for sale, no price quotations can be presented. Professor Baird also bears testimony to the fact that its flesh is very sweet and palatable, and Mr. Stearns states that its flesh is highly esteemed by many of the Gulf fishermen.

Bean (1891) does not seem to think so highly of it as a food fish, for he dismisses the subject by saying:

> The species is not an attractive one, and although the flesh is sweet and palatable, it is never eaten.

Gill (1907) found it good eating.

So far as the writer knows, this fish is never eaten at Beaufort. In July, 1908, he had some served at the laboratory mess and, discounting prejudice resulting from the unprepossessing appearance of the fish, its flesh was not only not unpalatable but was distinctly good, as good as or better than the majority of bottom fish caught in the harbor. But however good its flesh, Goode's prophecy for this fish can never be realized, because of the small size of the individuals, the limited numbers in which it is caught, and not least because of the great number of bones due to the presence of the long dorsal and ventral fins.[a]

LIFE HISTORY.

The life history properly begins with the formation of the male and female germinative products, the sperm and the egg, but before describing them it will be best to describe the organs of reproduction, the testis and the ovary, respectively, as found in the adult "ripe" fish at the other end of the life history.

ORGANS OF GENERATION.

The ovary.—This is fashioned after the ordinary teleostean type, as may be seen in figures 1 and 2, plate CVII, both of which are natural size. Figure 1*C* is of an unripe ovary which had been preserved in alcohol and photographed in the same. Figure 2 is a ventral view of an ovary excised from a pithed fish and photographed in water *alive*. Anteriorly it is bifurcated into two lobes, which join behind to form the short oviduct by which the eggs are carried to the exterior through the genital pore opening just behind the anus. In figure 1 the anus is shown and to the left of it one of the paired halves of the urinary bladder.

When the eggs are ripe, the ovarian walls are very much distended and semi-transparent, as shown in figure 2, where the large eggs are plainly visible, as are also the small ova—probably of next year's crop—lying between. The fine dark lines running over the ovary are blood vessels with which this organ is abundantly supplied. Extending lengthwise of the left lobe is a strand of tissue which seems to be a raphe. At the anterior end of each lobe are to be seen the remnants of the tissues by which the ovary is tied to the other organs. Internally each lobe is a hollow tube the walls of which are covered with ovarian eggs.

The ovarian eggs are inclosed each in its own short-stalked follicle, which is richly vascularized. When the process of spawning takes place, the eggs burst the follicles and fall into the lumen of the ovary and thence pass to the

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[a] Hargreaves (1904), writing of the allied *Batrachus surinamensis* of British Guiana, says that although its outward appearance is very much against it yet it "has the reputation of being the most delicately flavored fish in the whole colony."

exterior as described above. The eggs when extruded have the adhesive disk by which they become affixed to the nest. The formation of this disk and the manner of fixation of the eggs are points on which the writer is unfortunately able to give no information. The eggs are very large, measuring from 4 to 6 millimeters in diameter, the average being about 5 millimeters, as stated by Miss Clapp (1891 and 1899) and by Ryder (1886 and 1887).

The testis.—This organ, like the ovary, consists of paired elongated glands lying in the posterior dorsal part of the body cavity. They are confluent behind to form the sperm duct, which opens in the same place and manner as the oviduct. *A* and *B*, figure 1, plate CVII, show the dorsal and ventral surfaces of the ripe spermaries of a full-grown toadfish and are natural size. The long lobulated organs are the testes, the roundish dark structures are the paired lobes of the bladder, while the short whitish bodies (placed posteriorly and reaching right and left) are accessory glandular structures whose function is not known.

The spermatozoan is very large. The head is round in front, nearly as broad as long, flat behind where it joins the middle piece, which is almost as large as the head. The tail is not very long and the motion relatively slow. The sperms resemble nothing in the world so much as tadpoles with very large heads, and bodies but little smaller, behind which extend thin tails several times longer than the head and body combined.

FERTILIZATION AND EMBRYONIC DEVELOPMENT.

Natural fertilization.—The manner in which fertilization is effected in nature is not known, but it is interesting to note here the correlation between the size of the micropyle and the sperm. The former is so large as to be visible to the naked eye.

Artificial fertilization.—Neither Miss Clapp (1891 and 1899a), in her experimental work on the egg of the toadfish at Woods Hole, nor Miss Wallace (1898) had any trouble in artificially fertilizing the eggs, since ripe males and females were readily obtainable. At Beaufort scores of fish were dissected by the writer in the course of this research during 1906 and 1907, but while ripe males were abundant not a single ripe female was obtained. Fish were caught all over the harbor, the extreme points of capture being 3 to 3½ miles apart. On July 18, 1906, in a tank of fishes from Cape Hatteras, I received 12 toadfish. Two were given away, the sex of one could not be determined macroscopically, nine were males, and one was a female with immature ovaries. At Woods Hole females are more abundant than males, I am informed by Mr. Vinal N. Edwards.

During the summers of 1906 and 1907 not a single ripe female was captured, and but two with ovaries anywhere near maturity. One of these ovaries is shown in figure 2, plate CVII. The other was in about the same stage. On June 22, 1908, Prof. Raymond Binford, of Guilford College, N. C., in searching for *Ascaris*, killed a 6¾-inch toad which on dissection proved to be a female with ripe ovaries containing about 40 eggs. The ovaries were opened and the eggs were run into fresh salt water. A ripe male being at hand it was quickly opened and the testis was minced up and parts put into the same dish with the eggs. After about ten minutes the water with the minced-up testis was poured off and the eggs covered with fresh clean water.

Fertilization was effected about 12 noon. The eggs at 6 p. m. were in the 4-celled stage. Segmentation must have begun about 5, possibly as early as 4.30. At Woods Hole, Miss Clapp (1891 and 1899a) found that segmentation began seven hours after fertilization (artificial) was effected. In the above experiment, segmentation began within four and one-half or five hours after the eggs were impregnated. The explanation is undoubtedly to be found in the great difference in the temperature of the water. Miss Clapp does not give the temperature for her experiments, but at 3.15 p. m. on the day referred to a thermometer hung in running sea water in the Beaufort laboratory registered 81° F. In this difference in temperature of the harbor water at Woods Hole and Beaufort is also to be found the explanation of the ease with which Miss Clapp could get ripe females and of the difficulty I experienced in getting even one.

Owing to the low temperature at Woods Hole the breeding season for the toadfish is restricted to a comparatively short time. Dr. Raymond C. Osburn, of Columbia University, at my request, has carefully gone over the Woods Hole records. He writes me that they show that spawning goes on during the month of June only (except of course in some few sporadic cases), beginning sometimes as early as the first week in June. He writes that the most extensive and authentic records have been made by Mr. J. T. Patterson, who notes that in 1906 the spawning period extended from June 12 to June 25. Speaking for himself, Doctor Osburn says:

> It is my own experience that the eggs are mostly hatched by the first week in July; that is, they have broken the egg membranes. I know this because I have often looked for them here after coming the first of July, and I have never yet succeeded in finding eggs that were entirely fresh at that time.

In a letter to the present writer, dated July 24, 1906, Vinal N. Edwards, the veteran collector of the Fisheries Laboratory at Woods Hole, says that he does not find any toadfish with eggs after the first of July. He adds, however, that in the fall, when he sets his fyke nets, he catches large numbers of large fish full of spawn, but they carry it all winter.

Some older records for the Woods Hole region are as follows: Storer (1855) found eggs or young in June, July, and August; Goode (1884), at Noank, Conn., in 1874, founds eggs on July 14, and young one-half inch long on July 21, which had, on September 1, reached a length of 1 inch. Ryder (1886) says:

> Oviposition occurs about the middle of July in the latitude of Woods Hole. How long it lasts has not been determined, but judging from the condition of the roes and milt of the adults at that time, it seems probably that they do not spawn later.

According to Bumpus (1898):

> Oviposition occurs as early as June 3, and it may occur at any subsequent time throughout the month.

The higher temperature at Beaufort, however, allows the breeding season to be long drawn out. I have found advanced embryos the first week in June and eggs in segmentation late in August. Thus the spreading out of the time of oviposition makes it easy to find spent females and correspondingly hard to find ripe ones. I may add that no other ripe females have been found this season (1908).

Formation of the germ disk.—The germ disk was quite definitely formed as a fairly distinct white patch about three hours after impregnation. The streaming of the protoplasm to form this was in part preceded and in part accompanied by the collecting of yellow oil globules at the micropylar region. These oil drops, some large and some small, form in a layer under and visible through the germ disk in just the same fashion as the writer found in the egg of the pipefish, and as has been reported for a large number of teleosts. For a discussion of the matter see Gudger (1905). Miss Wallace (1898) also reports oil globules in the egg of this fish. The streaming of the protoplasm continues after the segmentation has begun, thus the germinal disk grows constantly larger for awhile by these additions of protoplasm. Ryder's (1886 and 1887) error in saying that there are no oil drops in the eggs of the toadfish is hard to explain save on the supposition that they disappear by the time those stages on which he worked are reached.

Segmentation.—As already stated, segmentation begins seven hours after fertilization at Woods Hole, five hours after that act at Beaufort. The germinal disk divides in a vertical plane into two cells, then along another plane, at right angles to the second, into eight cells. The segmentation into two and four cells results in blastomeres about equal in size and symmetrical in place. But beginning with eight cells and continuing on until division is ended, the segmentation is very irregular, growing more so with each division.

Notwithstanding the large size of the yolk, the blastoderm never piles up high with a clearly defined circumference as is found in the Salmonidæ, whose eggs are about the same size, and as the writer found to be the case in the pipefish (Gudger, 1905), whose eggs are only one-fifth (1 mm.) as large. On the

contrary, even during the early stages of segmentation—8, 16, and 32 cells—the blastoderms flatten out, the cells on the periphery presenting an appearance which can only be likened to that taken by a pellet of soft mud when thrown against a smooth wall. To say that the blastoderms present an extraordinarily irregular appearance, but feebly expresses the fact. In some cases it looks as if the segmentation had begun at the center and worked outward, as Watase (1891) has shown in the squid. The explanation of the whole matter is to be found, I think, in the fact that segmentation begins before the flow of the protoplasm into the germinal region has ceased.

To the best of the writer's knowledge, the only work other than experimental done heretofore on the segmentation of the egg of the toadfish is to be found in Miss Clapp's paper published in 1891. Here she figures stages from two to sixteen cells, inclusive, the later blastoderms being very irregular.

Figure 3, plate CVIII, shows the right valve of a *Pinna* shell containing eggs in segmentation one-half natural size. This reduction was made in order that this half of the nest might be shown in its entirety. The photograph portrays a nest typical in all respects, the irregular manner in which the eggs are affixed, the crowding together—some eggs being on top of others as cannon balls are piled—and last, but by no means least, the fact that the eggs are in two stages. For the most part they are in late segmentation, but on the upper right-hand part of the shell some two dozen are still in early division, as the small size and somewhat rounded outline of the germinal disk show. Figure 4, plate CVIII, shows another nest with eggs in segmentation intermediate between the two stages shown in the previous figure. Here the eggs are shown twice their natural size in order to bring out details more clearly. Recalling to the reader's attention the fact that the micropyle is practically always found opposite the point of attachment of the egg, it is interesting to note that some of the blastoderms are not "opposite the point where the ovum is attached" as Ryder (1887) states, although this is generally true. Of especial interest is the fact that there are in this nest some half dozen eggs with divided blastoderms. Should these have come to maturity it is my opinion that they would have formed twins. (For a much magnified figure of such a blastoderm see the writer's paper on the pipefish, 1905, plate VI, figure 26, and for the histology of the same, plate VIII, figure 54, and plate IX, figure 55.) Miss Clapp, in the paper referred to in the preceding paragraph, figures such a divided blastoderm in the 8-celled stage.

Invagination.—The next stage in the history of the eggs whose development we are studying is that in which, segmentation having ended, the blastoderm flattens out into a thin cap of cells covering about one-fourth the upper half of the egg. Shortly thereafter it is the rule in teleost eggs that the edges of this protoplasmic cap begin to turn in under the cap and between it and the yolk. Technically this is called invagination, the in-pushing cells making a distinct

rim to the edge of the cap and inclosing a clearer space known as the segmentation cavity. This condition of things, however, does not seem to exist in the egg of the toadfish.

Miss Wallace (1898) has shown in a short but highly interesting paper that there is no true invagination in this egg, but that the apparent thickening, the appearance of a germ ring or invaginating blastoderm, visible as the protoplasmic cap grows down over the yolk, is due in part to an ingrowth of cells from the ectodermic layer, but chiefly to the greatly thickened periblast filled with giant nuclei.

The writer regrets that he can present no photograph of this stage, as these structures can only be brought out clearly in eggs killed for the purpose, while his photographs are all of living eggs. He has had no opportunity to verify by means of sections the conclusions above stated. Eggs properly "killed" seem to show a very distinct germ ring, and, had he had not been aware of Miss Wallace's work, the writer would, from surface views, unhesitatingly have described the condition as a case of invagination.

Formation of the embryonic shield.—The cap of cells described above continues to spread over the upper hemisphere of the egg, growing thinner all the while. Presently at one point on the rim there appears a slight flattening tangential to it, causing the cap to become bilaterally symmetrical in one plane only, this plane being the axis of the future embryo. According to Miss Clapp (1891), the notch or bay described below is formed at the central point of this flattening during this stage. So far, however, as I have examined my material I have found nothing to corroborate her statement. No photograph of this stage is presented for the same reason as given above.

Differentiation of the embryo.—During all the events described above the blastoderm has been growing larger and extending over the yolk. After passing the equator of the egg, the opening, the morphological blastopore, grows smaller and eventually closes. Growth seems to go on less rapidly at the posterior end of the axial thickening—i. e., that connected with the rim of the blastoderm, the anterior free end extending out into the center of the cap—which results in the formation of a little bay at the hinder end of the forming thickening. Then, as the spreading of the cap over the yolk continues, the blastoderm grows backward away from the embryonic rod, leaving it connected with the edge of the cap by a slender cord of cells. This formation of the embryo is, I believe, peculiar to the toadfish. It was first demonstrated from surface views by Miss Clapp (1891), whose work was verified and extended by her pupil, Miss Wallace (1898), who cut sections of the egg in this stage.

At Woods Hole the axis of the embryo first becomes visible on the seventh day, according to Miss Clapp (1891). Miss Wallace (1898), however, detected an "axial thickening" on the fourth or fifth day. Artificial fertilization not

having been effected at Beaufort, I can not give the time definitely; but from three separate broods of early eggs found in the harbor it can be stated that between forty-eight and sixty hours after impregnation the embryonic axis begins to form.

These structures are for the most part too delicate to be shown in photographs of living eggs. Figure 5, plate CIX, shows the board nest frequently referred to. It contains eggs in two stages of development, spreading blastoderms and rod-like embryos, and likewise the crowding always found in the eggs of a large nest. The board and eggs are natural size and all the eggs are shown save a few at each end. If studied with so low magnification as that afforded by even an ordinary reading glass, the young embryos, as yet possessing no trace of fishlike characters, may be seen as axial rods. Close scrutiny will reveal the fact that one end—the future head end—is slightly larger than the other.

Figure 6, plate CIX, shows half natural size another board nest of large size. The embryos here are considerably older than the preceding. The head end has noticeably enlarged, the ventricles of the brain are visible (under a low power), the eye vesicles are forming, the pectoral fin buds are not visible but are clearly marked off at this stage. In short, the embryonic fish is outlined.

Even a momentary glance at the positions of the embryos will completely negative Ryder's (1886 and 1887) statements that the embryos "invariably" point in one direction.

By taking the nests out of the aquariums and examining them from day to day the development can be followed step by step. The eye vesicles are formed, the blastopore closes, the pectoral fins grow in size, the tail becomes free, the heart is formed and begins to beat, a vascular system is formed and spreads over the yolk, and, finally, growing dissatisfaction with its narrow quarters is expressed by the little fish through writhings and shiftings of the tail from side to side.

THE LARVAL TOADFISH.

Early stage.—The condition of things described in the preceding section is not destined to continue longer. Presently the time arrives when, the shell having grown weak (rotten is the way my notes put it in numerous cases), the little fish bursts that part over its head and, taking in a mouthful of salt water, passes this back over its gills and is ushered into a new world as the just-hatched larva of the toadfish.

Usually the shell bursts first over the head and back, setting the head parts free; then the split, continuing backward, sets the tail free. Sometimes, however, the shell bursts over the tail first. In this latter event one will see a wildly waving tail, which by its lashings continues the split forward and uncovers the head. Eventually the shell splits down in several directions and not only uncovers the embryo but the upper half of the yoke as well.

As clearly as I can determine (artificial fertilization not having been possible), the bursting of the shell takes place eleven days after fecundation. Ryder (1887) says that on Chesapeake Bay the incubatory period lasts from ten to fifteen days. According to Patterson (quoted in Osburn's letter to the writer): "In 1906 young fish at Woods Hole broke the capsule in twenty-six days." The difference in the time of hatching at Woods Hole and Beaufort is plainly due to the difference in temperature of the water, the higher temperature at the latter place greatly hastening development.

Figure 7, plate CX (one-half natural size), shows one-half of a nest of eggs in the early larval stage. Whether it is a photograph of the shell shown in figure 3, plate CVIII, I can not say positively, since my records are not clear on this point, but I believe that it is. The tadpole-like appearance of the young spoken of by writers is very apparent. As in most shell nests at this stage the embryos point in one general direction, but toward the hinge rather than the opening of the shell, and consequently away from instead of toward the light, as Ryder (1886 and 1887) positively asserts.

Figure 8, plate CX, shows the same board nest shown in figure 5, plate CIX, and represents the larvæ in natural size and in a stage of development slightly older than the preceding. Here the embryos point in all directions, as stated in the first part of this paper. The tadpole-like structure is very apparent, due to the broad, flat head with its opercular flaps, just back of which are the pectoral fins, the largest organs with which the fish is provided at this stage of its development.

There may be plainly seen in this figure the empty shells still adhering to the nest. The eggs have either died and been removed to prevent the spread of disease or they have been taken away for preservation in alcohol for further study. The empty shells with the adhesive disks are very resistent to decay, but finally the gluey substance by which they are affixed becomes loosened and they may readily be removed.

The pectoral fins have been referred to. Their formation precedes in time and position the formation of the pelvics. These latter originate at this period as two folds just back of the pectorals. As the fish develops these become "translocated," as Ryder (1886) puts it, to their permanent jugular position. Both Ryder (1887) and Miss Clapp (1899) have figures of the just-hatched toadlet which show these fins and also make clear the fact that there is no definite caudal fin at this stage. Miss Clapp's admirable drawing of this stage has, however, three serious defects, i. e., the larva has neither mouth nor gill slits, both of which in a very rudimentary condition are present, and the extremity of the tail turns downward instead of upward, as Ryder correctly shows.

Under favorable conditions the embryos make steady progress. The head and mouth parts grow more perfect, the gill covers and pectorals become more

thoroughly functional, the vascular system spreads over the yolk and brings in digested food with the concomitant rapid enlargement of the embryo, the pelvic fins rapidly grow forward to their permanent position, and the other fins, dorsal and caudal, are formed. Presently the bands and markings begin to appear faintly. The embryos, which at the beginning of this stage looked more like tadpoles, larval frogs, than larval fish, now begin to look not merely fish-like,. but decidedly toadfish-like.

Late stage.—There is no marked event to set apart the early and late larval stages as the bursting of the shell delimits the former from the purely embryonic forms. So for the sake of convenience I will (somewhat arbitrarily) choose the appearance of the color bands as making the distinction, since their appearing does to some degree divide the larval life into fairly definite stages.

These markings first appear in the tail region as three faint bands of grayish color, one at the root of the caudal and two across the median portion of the tail. A little later a fourth band appears in the region of the spinous dorsal, and finally a smaller band running transversely to the rays of the caudal adds much to the appearance of that organ. The two transverse bands on the tail gradually extend into the long dorsal and ventral fins and, aided by the diversified coloring of the head and by the St. Andrew's crosses in the iris of the eyes, give the little fish a really beautiful appearance. An inspection of figure 13, plate CXIII, numbers 1 to 7, will make clear all these points. In this photograph the larvæ, specially "killed" and preserved in alcohol, are enlarged two diameters.

Figure 9, plate CXI, represents a nest of late larvæ twice natural size. Unfortunately the fish at this stage were almost the color of the nest (a *Pinna* shell), and they do not show up very clearly. The growth of the larvæ, however, from the stage shown in the preceding paragraph is very apparent.

Somewhat older are the toadlets shown in figure 10, plate CXI, which is an instantaneous photograph (natural size) of the nest shown in figures 5 and 8. Not only is the focus better than the preceding photograph, but the contrast between the color of the board and that of the young is so strong as to bring out the latter very distinctly. Both the mottlings on the head and the bands across the body are very distinct. The larvæ are very toadfish-like with their broad heads and large pectorals. In passing it should be noted that the heads of the fish point in all directions. The young are very active, lashing right and left with their tails continually, and in this observation I am in disagreement with Ryder (1887), who says that, while the young are still adherent, the little fish keep up a rapid motion of the pectorals, to aid in carrying away the water from the gills, while the tail is comparatively still. I find that the pectorals rarely show any motion, while the tails are more frequently in motion than at rest, until the last few days before the young detach themselves. At this late period their

tails are more frequently still than in motion, while the pectorals keep up a slow but continual fanning motion, broken at intervals by a few impatient strokes.

Figure 11, plate CXII, is an instantaneous photograph (natural size) of the nest shown in the preceding and in other photographs. Here the young are ready to break away. They are in continual motion, lashing with their tails, swinging back and forth, even twisting in their efforts to break loose from their anchorage. This is apparent in the figure in the blurred effects, which are due to the motion of the little fish while the plate was being exposed. While one is looking one or more little fish may break loose and swim rapidly away, seeking at once a place of safety under the board or in holes in it. As best I can determine, at Beaufort detachment is effected twenty-four to twenty-six days after fertilization. An allowance of two or three days must be made for variations in the temperature of the water, the degree of virility of each little fish, and external stimuli, such as fear or some mechanical shock, exciting the larvæ to greater action. Ryder (1887) approximates the fixed condition at from three to four weeks at Cherrystone, Va. At Woods Hole the young became free in 1906 on the forty-second day, according to Patterson's notes forwarded to the writer by Osburn.

I am satisfied that these larvæ begin to feed before they detach themselves from the nest. Small crustacea, and indeed anything which would serve as food for them, would be drawn into their mouths by the action of the opercula and, being caught by the gillrakers, would be passed down their gullets to the stomach.

A curious phenomenon found only, so far as the writer's knowledge goes, in the young of the toadfish, must now be described. The egg remains spherical so long as the egg membrane exists intact, but immediately after the larva bursts this the yolk begins to elongate and presently a constriction appears. This constriction appears at first to be due to the yolk pouring over the torn shell, but as time passes and the shell is burst wide open, it is apparent that it is due to other causes.

Before going into the explanation of this curious constriction, it will be proper to give a fuller description of the phenomenon itself. On looking at some eggs but a few hours after hatching, at say 5 p. m., to make a hypothetical case, we find the little embryo sitting on top of the rounded yolk; some hours later we find it on the summit of a pyriform eminence, to use Ryder's (1887) expression; next morning we may find the yolk-sac still elongated but having a slight constriction at or near the middle (like a pillow or bolster with a rope tied around it), or drawn out into a pillar-like body sometimes as long as or even longer than the embryo itself. Later still the yolk may round up and then again go through the same series of changes described above, not necessarily, however, in the same sequence, but with the order perhaps varied or some steps in the series omitted. The changes in form of the yolk bag are, however, more or less rythmical.

Finally, about the time that the color bands make their appearance, the yolk sac takes a certain very definite appearance. The constriction appears at the upper part of the yolk and divides it into a small upper and a large lower bulb (Ryder, 1886). The lower bulb sits inside the remnants of the egg shell, the upper is partly inclosed in the down-growing body walls. As the fish grows larger and can accommodate within its body more yolk, the constriction travels toward the base or point of fixation of the egg. Presently the yolk sac takes on the hour-glass shape to which Ryder (1887) refers and which he figures so well. Finally all the yolk has been driven into the body of the larval fish and there is nothing left save the placenta-like mass of blastoderm filled with blood vessels. Figure 13, plate CXIII, numbers 1 to 6, shows the various changes in the yolk sac as the constriction travels toward the base. This photograph is made from "killed" eggs in alcohol.

The explanation—the only one, so far as I know, ever proposed—is to be found in a little-known oral communication of Ryder to the Philadelphia Academy of Natural Sciences on November 4, 1890. In this he makes known the notable discovery that in the yolk sac of the young *Opsanus tau* there is a layer of *smooth* (italics mine) muscle fibers underlying the epidermis and presumably originating from the splanchnic mesoblast. This muscular layer in turn is composed of layers of spindle-shaped fibers. One layer runs around the yolk bag in equatorial fashion, the fibers of the other run at right angles to the first. Given these facts, the explanation of the changes taking place in the form of the yolk sac is at hand. This is a most interesting point, and, in so far as the writer knows, nothing like it has ever been discovered in any other fish, and great credit is due Ryder for working it out. Ryder surmises that possibly it may have a double function, i. e., not merely that of forcing the yolk into the abdomen of the embryo, but likewise of strengthening the yolk bag so that no injury results from the energetic movements of the fish in its attempts to set itself free. To the present writer this seems to be beyond question the correct interpretation.

THE FREE-SWIMMING YOUNG TOADFISH.

The little toads which have just torn themselves away from their anchorage, if looked at from above, appear to differ from adults only in size; but if viewed on the ventral surface they show the placenta-like stalk to which reference has been made in the preceding paragraph, and to which not infrequently the adhesive disk is still attached. In a few days the disk (if present) drops off, the placenta-like stump is absorbed, leaving only a knob-like projection in the jugular region. Later this disappears and our little fish is no longer a larva but a toadfish, differing from its parents only in size and the stage of development of its reproductive organs. Numbers 5, 6, and 7, figure 13, plate CXIII, show the various

stages in the final absorption of the yolk, the formation and disappearance of the lower yolk bulb or placenta-like stump. The fish are enlarged two times.

Figure 12, plate CXII, is from an instantaneous photograph of part of the brood from the board nest of which a series of photographs has been shown. These toadlets (natural size) are in the stage described above, and, in their markings, their bendings of the tail, and their crowding together, show the typical toadfish characteristics.

THE ADULT TOADFISH.

What is the rate of growth in the toadfish? How long is required for it to reach maturity? What is the normal and what the maximum sizes of the fish? These are questions pertinent to this research, but unfortunately not so easily answered as asked.

The little toads at hatching at Beaufort are from 16 to 19 mm. long (⅔ to ¾ of an inch). Storer gives a length of ½ or ¾ of an inch for those at Woods Hole. Greene (1899) says the young of the Pacific form, *Porichthys notatus*, are about 1 inch long when they become free-swimming. According to Smith (1907), on March 26, 1904, a specimen 1.37 inches long was taken in a seine at Beaufort. This must have been hatched late in the preceding season. I have taken them in June and July about 2 inches long. Not infrequently specimens 3 to 6 inches in length are taken in *Pinna* shells. Goode (1884) gives the length of the season's brood in September at 1 inch and adds: "Individuals, apparently of the second year's growth, were also common, and would average three-fourths of an inch in length." Doctor Gill (1907) says of this, "A statement contradicted by the context and probably a *lapsus calami* for 3 or 4 inches." For myself I am thoroughly satisfied that the 3 and 4 inch individuals met with are of the preceding year's brood.

A very incomplete series of measurements of specimens taken at Beaufort in seines by the writer in 1903 and 1904 runs from 3½ to 8 inches in length. These, however, are smaller than those previously referred to as caught and made use of in this work. The following are recorded in my notes because of their unusual size: Males, one 10, one 11½, and another 12½ inches in length; females, one 10, another 10½, a third 12 inches long; sex not determined, one 12-inch specimen. It is greatly to be regretted that a complete list of measurements of all specimens was not kept. The writer's judgment, however, is that they would measure 7 to 12 inches from tip of nose to end of caudal, with an average of about 9 inches.

Mitchill (1815), the first American describer of this fish, says the length is about 12 inches, breadth about 4, depth 2. Yarrow, writing of Beaufort toadfish, in 1877, says that a length of 4 to 8 inches is the most common. Le

Sueur (1824) could find no specimens longer than 5½ inches. De Kay (1842) gives the average size as 6 inches, but had seen them up to 1 foot long. Goode (1884) says of the "northern variety" (*Batrachus*, now *Opsanus*, *tau*) that it rarely exceeds 10, 12, or at the most 15 inches in length, and quotes Silas Stearns, that the southern species (*Batrachus*, now *Opsanus*, *pardus*) frequently attains the length of 18 inches. Jordan and Evermann (1898) give the length as 15 inches, meaning, I take it, that this is the maximum. Miss Clapp (1899), writing of the Woods Hole toadfish, says that a specimen 12 inches long is seldom met with. Smith (1907) fixes the maximum size for Beaufort specimens at 15 inches. The writer's experience is that a 12-inch specimen is rather rare, and that the average length of sexually mature fish is from 7 to 10 inches. Hence if a fish in one year attains a length of from 3 to 4 inches it will probably require two to three years to attain sexual maturity and three to four years (since growth takes place more slowly as the fish becomes older) to attain the average maximum size.

The largest fish of this species ever seen by the writer was 14½ inches long, a veritable giant of his kind. He was anesthetized and carefully measured. These measurements are herewith reproduced: Length, tip of nose to end of caudal, 14½ inches; width across head, 4⅞ inches; width between eyes, 1¾ inches; girth of head, 4⅞ inches; girth of body at anterior base of pectorals, 11⅞ inches; girth of body at posterior base of pectorals, 11½ inches; girth of body at anus, 6¾ inches; mouth (wide open) width, angle to angle, 3¼ inches; height, top to bottom, 2⅝ inches.

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FIG. 1.—Reproductive organs of the toadfish. A, dorsal; B, ventral aspect of ripe testis from adult male; C, dorsal view of immature ovary. Photographed in alcohol

FIG. 2.—Ventral aspect of living ripe ovary of toadfish. Photographed in water.

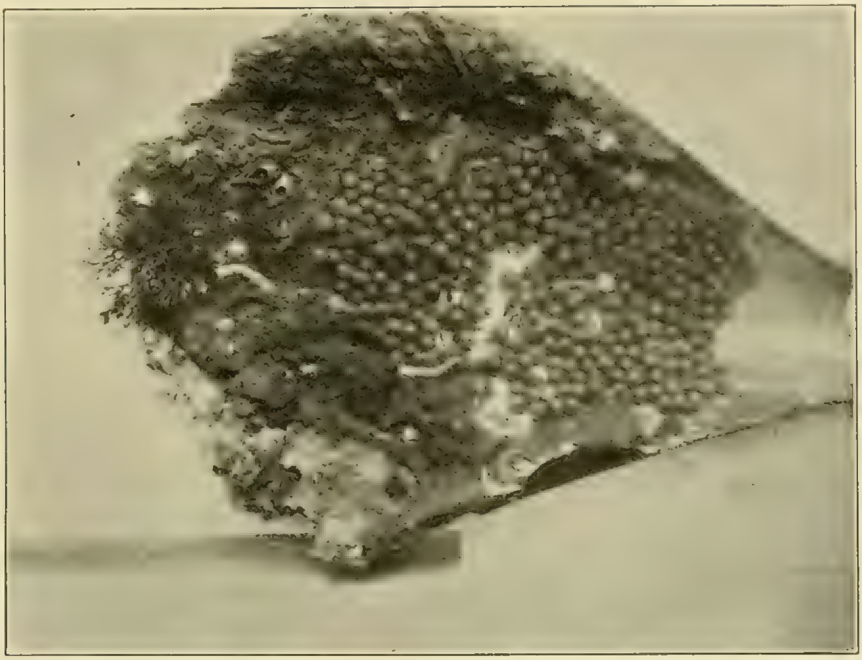

FIG. 3.—One-half of *Pinna* shell nest, showing live eggs in segmentation. ×½.

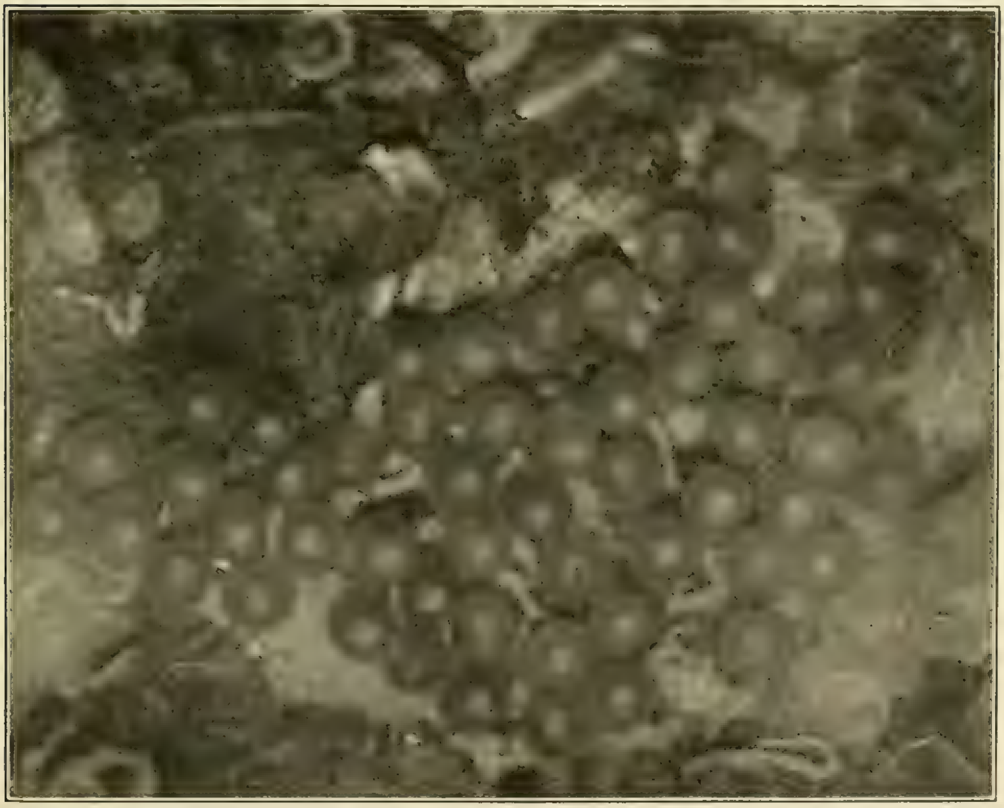

FIG. 4.—Eggs (×2) in late segmentation. Photographed alive in water.

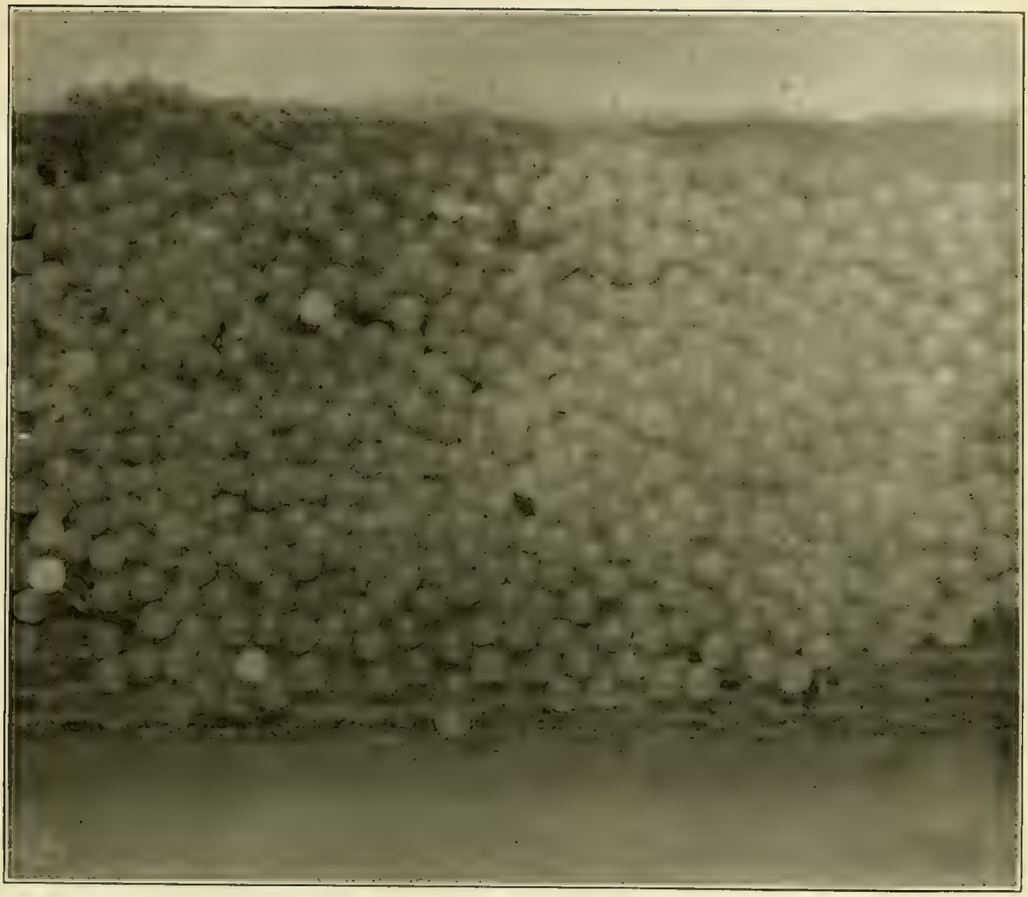

FIG. 5.—Board nest, eggs with late blastoderms and early embryos. Natural size.

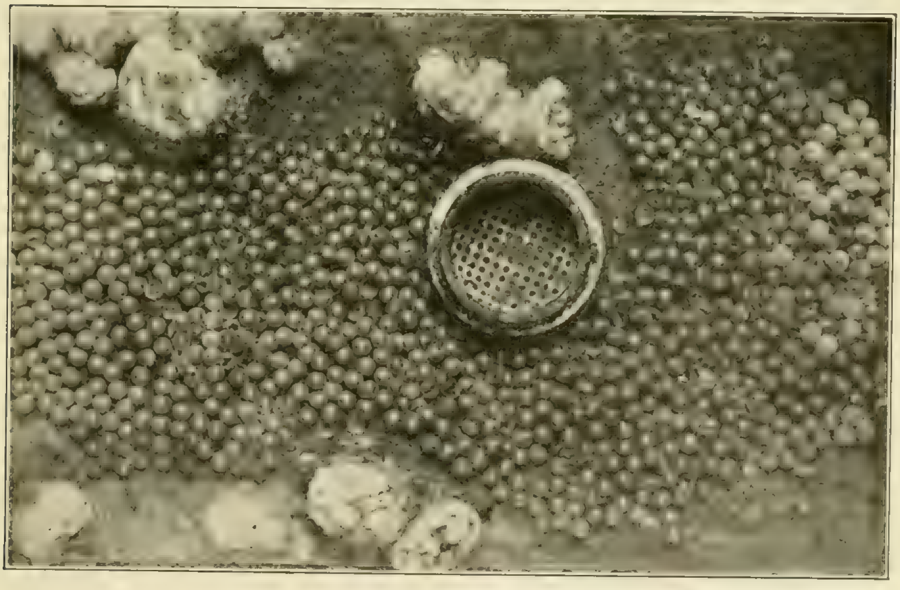

FIG. 6.—Nest showing embryos having a marked enlargement at one end. ×½. (White eggs to right are dead.)

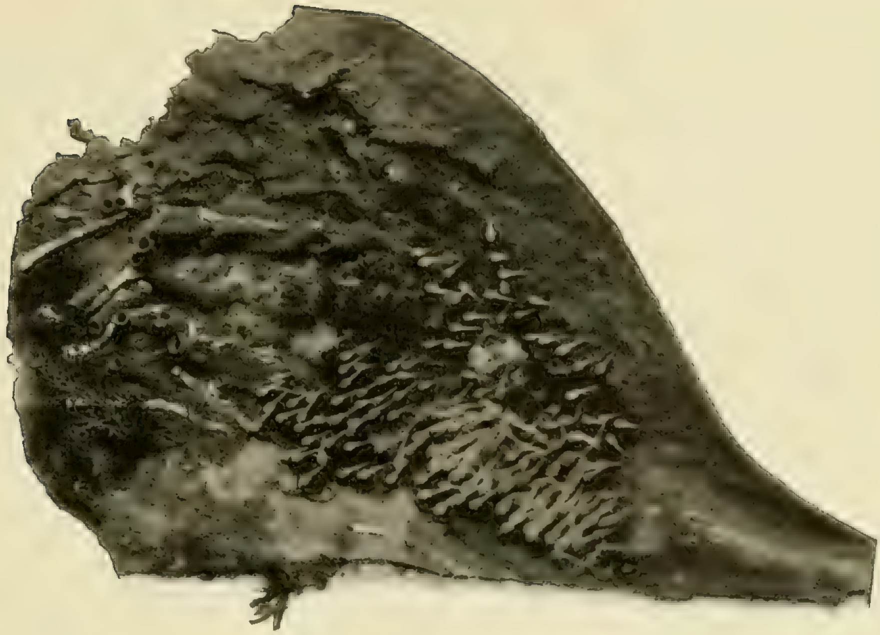

FIG. 7.—*Pinna* shell nest, showing tadpole-like larvæ. ×½.

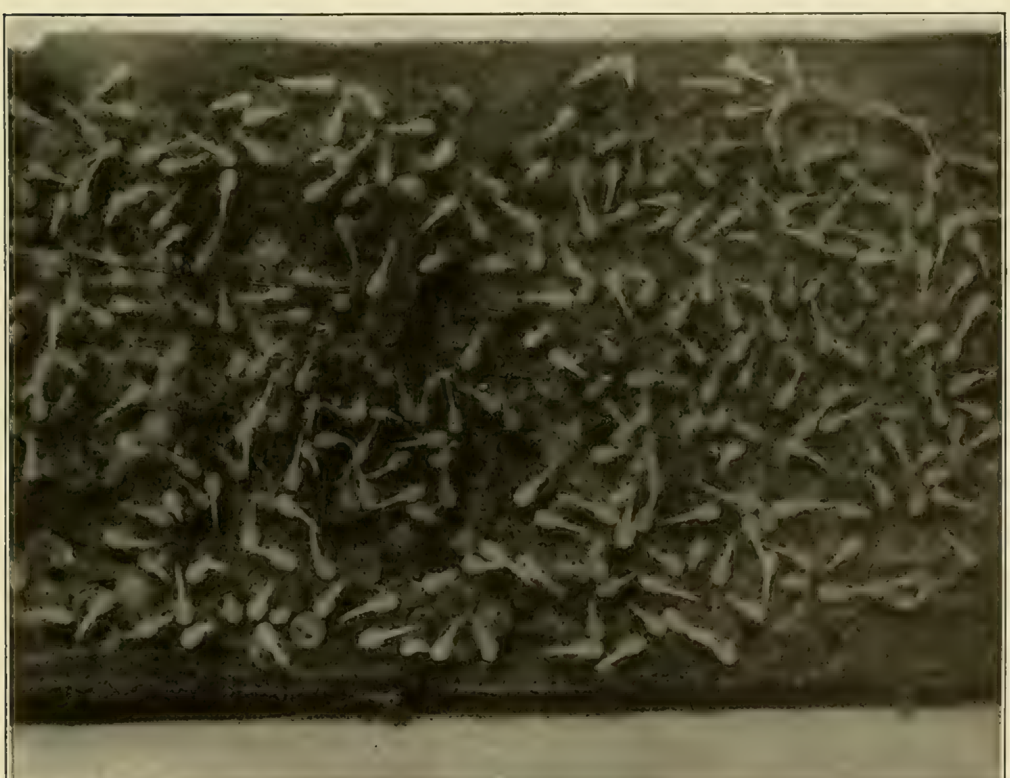

FIG. 8.—Board nest. Larvæ slightly older than in figure 7. Natural size.

FIG. 9.—*Pinna* shell nest, late larval toadfish. ×2.

FIG. 10.—Late larval toadfish, showing color markings. Natural size. Same nest as figure 5, plate CIX, and figure 8, plate CX

FIG. 11.—Same nest as figure 10, plate CXI. The young are nearly ready to break away.

FIG. 12.—From an instantaneous photograph of free-swimming young toadfish in water.

FIG. 13.—Larval toadfish (× 2), showing formation of the color bands and disappearance of the yolk. Photographed in alcohol.

METHODS OF STUDYING THE HABITS OF FISHES, WITH AN ACCOUNT OF THE BREEDING HABITS OF THE HORNED DACE

By Jacob Reighard

Professor of Zoology, University of Michigan

Paper presented before the Fourth International Fishery Congress, held at Washington, U. S. A., September 22 to 26, 1908 and awarded the prize of one hundred dollars in gold offered by Theodore Gill for the best methods of observing the habits and recording the life histories of fishes, with an illustrative example

CONTENTS.

	Page.
I Methods	1113
General principles in field study of fishes	1113
Habituation of fish to observer	1113
Determination of species	1116
Analysis of observations	1116
Repetition of observations	1117
Importance of field experimentation	1117
Making of records	1117
Compilation of observations	1118
Times and places of observation	1118
Means and devices for observation	1119
Note-taking materials	1119
Field glasses	1120
Water glasses	1120
Photographic methods	1122
II. Illustrative example	1125
Breeding habits of the horned dace	1125
Observing the fish at nest-building time	1125
The nest-building process	1127
Protection of the nest against other fishes	1128
Spawning behavior of male and female	1129
Security of nest structure	1132
Destructive agencies	1133
Summary of observations	1134
Literature cited	1135

METHODS OF STUDYING THE HABITS OF FISHES, WITH AN ACCOUNT OF THE BREEDING HABITS OF THE HORNED DACE.

By JACOB REIGHARD,
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I. METHODS.

The studies upon which this paper is based have been made in the field, on fishes in their natural environment. Captive fish have been used only when necessary to supplement field observations. As the result of this work, extending over somewhat more than fifteen years, there have been developed certain methods which it is the purpose here to describe. These are, of course, essentially field methods. The studies that produced them related to the natural history of the dogfish (*Amia calva* Linnæus), work begun in 1891 and published in 1903; the habits and development of the black bass (1903); the habits of coral-reef fishes at Tortugas, Florida, published in 1909; and more or less complete observations about ready for publication on *Lampetra wilderi*, *Catostomus commersoni*, *Catostomus nigricans*, *Moxostoma aureolum*, *Campostoma anomalum*, *Pimephales notatus*, *Semotilus atromaculatus*, *Rhinichthys atronasus*, *Notropis cornutus*, *Hybopsis kentuckiensis*, and half a dozen sunfishes of the family Centrarchidae. Work by the writer's students on the breeding habits of local fishes (Reeves, 1907, B. G. Smith, 1908) has also been utilized.

GENERAL PRINCIPLES IN FIELD STUDY OF FISHES.

Habituation of fish to observer.—When an observer approaches a fish for the first time it nearly always happens that the fish is disturbed by the sight of him or by some sound that he makes, and forthwith retreats into deep water or into some nearby cover. The inexperienced observer usually considers such a fish as lost to observation for good and very likely passes on in search of some less wary subject. In doing this he is governed by the popular impression that fish are rovers, not bound to any one locality, and that it would therefore be useless for him to await the return of this particular fish to the locality in which he first saw it. If it were a bird or a mammal he might at least follow it in its wanderings, but with a fish this is manifestly impossible.

In passing to a new subject for observation the inexperienced worker makes a fundamental error, for, save under exceptional conditions, fish are

local in their habits. A fish frightened from a particular spot will ordinarily return to it if the observer have but the patience to wait. While waiting, he must not move, but must hold himself as immobile as a tree, so that to the fish, very likely watching from some lurking place, he becomes a part of the landscape. After a longer or shorter time the fish will return, but is likely to be again frightened by a nearer look at the intruder. His second return will follow after a shorter absence, and his third, if again frightened, after a still briefer time. Thus gradually the fish will become habituated to the presence of the observer and will take no further note of him. Then the observer may move about slowly. Let him not move even his head or his hand quickly or the fish will be again frightened, and the whole procedure will need to be recommenced. But if he is careful to begin with moderation he may gradually increase the range and rapidity of his movements until he has come quite near the fish and is moving at his accustomed rate. During this time he may talk or make other sounds in air, for sound waves in air do not disturb fish in water; but he must take care not to set up vibrations in any solid body so situated that these vibrations will be transmitted directly to the water. Thus, if he is in a boat or standing on a wharf he must not strike it violently. If on shore, he must do nothing to cause vibrations of the ground. If wading in the water, he must be careful to lift his feet slowly, so that there will be no splash or dribble, and to set them down with equal care. After a time he will find that the fish resumes the occupation in which it was engaged when first disturbed, and he may then observe it at his leisure; but the time that will be required before the fish will take no further notice of the observer, the nearness of his possible approach, and the extent to which he may expose himself to view or move about will vary with the kind of fish under observation and with its condition.

There is a very great difference in the readiness with which different species of fish become habituated to the presence of the observer, so that some may be said to be much more timid than others. This is well illustrated on the coral reefs. As an observer approaches such a reef by wading, all the many species which frequent it disappear at once into the shelter of the tortuous recesses of the reef. If the observer stands motionless and waits, the fish soon reappear, not all kinds together, but first the less shy species and last the more timid. Among the shyest of our local fishes are the suckers of the genus *Catostomus* and the black bass, while among the boldest are the common sunfish and related species. Not only does the rate of habituation to the presence of an observer vary from species to species, but, as I (1903) have had occasion to observe in the fresh-water dogfish, *Amia*, it may vary also from individual to individual. The successful observer of fish in their native haunts must therefore take account of this difference in shyness of different fishes and must be

governed accordingly. In studying the suckers it is usually necessary to remain very quiet and hidden behind some suitable shelter; but if the suckers happen to frequent the neighborhood of a bridge where there is frequent passing they become gradually used to the presence of human beings, and may then be watched without observing any unusual precautions. The black bass may be observed only by taking the utmost care not to disturb it, while the common sunfish (*Eupomotis gibbosus*) may, under most circumstances, be approached without difficulty.

In addition to the differences between species with reference to the readiness with which they become habituated to the observer, there are differences in the same species at different seasons. The areas suitable for the breeding activities of most species are of limited extent. On these areas the individuals of the species congregate at the breeding season, and it is then that they are most readily approached. If in addition to frequenting a particular breeding ground a species is in the habit of building nests, its activities are then centered about areas of still smaller extent, and it becomes proportionately easy to observe them. The breeding season therefore offers the best opportunities for observing the habits of fishes, not only because the fish are then gathered into limited areas, but also because they are easily approached on these areas and readily return to them when frightened away.

The tie which binds breeding birds to the nest and young has been made use of by Herrick (1902) in his remarkable studies of the "Home Life of Wild Birds." He has sawed off the supporting branch and thereby transferred nests from inaccessible trees to places more convenient for observation. The parent birds after recovering from their brief fright returned to their duties, while he watched them from a tent set up within two or three feet of the nest. He found that this parental instinct which, like a chain, binds the bird to its nest and makes it follow wherever the nest is carried, varies in strength at different times and in different birds. The nest should be moved for purposes of study at that time at which the parental instinct is at its strongest.

The like is true of fishes. A fresh-water dogfish may be readily frightened from its nest before the eggs are laid in it, but is much less easily frightened after the nest has been filled with eggs or the young fish hatched. The common sunfish becomes so tame when it has eggs in the nest that, as Thoreau (1849) long ago found, one may stand astride of the nest, stroke the fish on the back, and feed it from the hand. One may even lift the fish from the water in the hand, and when it is returned it will resume its parental duties. In like manner Miss Reeves (1907) found of the breeding rainbow darter (*Etheostoma coeruleum*):

> They quickly become accustomed to one's presence and are not then disturbed by one's wading among them. I have touched them with my boot tips or stroked them with a small wire without their moving. It is then possible to stand directly over them and even to examine them with a hand lens without in any way modifying their normal behavior.

Determination of species.—When the fish have become habituated to his presence the observer must, of course, learn to distinguish unerringly the species which he is studying from other species with which it might be confused. Workers who distinguish alcoholic fish at a glance may be puzzled to separate species of living fish in the water. Here it is impossible to count scale rows, pharyngeal teeth, or fin rays. On the other hand, the colors of the fish and their mode of movement and the fact that species difficult to separate are not usually associated make it comparatively easy to distinguish living fish in the water. Yet the literature contains many instances of errors which have arisen from the wrong determination of fish in their natural habitat. Safety lies in much collecting and repeated comparison of the fish in the hand with that in the water. After a time the observer of fish acquires something of the skill of the field ornithologist, who recognizes by its method of flight the bird that is so distant as to be a mere speck in the sky or by the wag of its tail or the tilt of its head the one that is almost hidden in the bushes. So the ichthyologist finds that living fish present characters that make their field determination easy and that are not set down in the books. But he must discriminate, not only between species, but between male, female, and young, and this is a much more difficult matter. Lack of critical method in discriminating between the sexes has led to very many errors recorded in the literature of the breeding habits of fishes. Until very recently there was perpetuated the error that the female of the black bass builds the nest and cares for the young, and a like error existed in respect to the dogfish (*Amia*).

Analysis of observations.—When the observer of fish habits has successfully approached his subjects and has learned to distinguish between males, females, and young, he is usually confronted by such a bewildering maze of behavior that he sees but little clearly and is sorely tempted to patch out that little by conjecture as to the rest and to aid his patching by analogies drawn from other groups of animals. There is here but one safe rule of procedure, familiar enough in other fields of science, but too little applied in the field study of animal habits. It is that the observer must proceed analytically; he must take one element of the behavior at a time and study that until he can describe it accurately. What is the precise position of the male and female in a pair of spawning fish? To answer this question accurately the observer must ask himself many others. What is the position in each fish separately? In each sex, what is the position of the tail, the head, the dorsal fin, the anal fin, the pectoral fin, the pelvic fin? Each of these questions must be answered by a separate observation, many times repeated, and only when they have been answered and the answers put together does one know the position of the two sexes in the spawning pair. Only by securing answers to innumerable and apparently unimportant questions, only by constant "Fragestellung" does one make progress in the field study of

animal behavior. Every accurate and complete account of such behavior is made up by putting together such answers.

Repetition of observations.—Many observations are necessary on each point. A single observation rarely suffices to answer any one of the many little questions that the observer puts to himself. The rapid movements of fishes in a more or less turbid medium, the surface of which is rarely wholly smooth, make observation difficult and increase the chances of error. The writer has in the case of some difficult points repeated his observations a hundred or more times before he has felt sure of their correctness.

Importance of field experimentation.—Field observations should be checked, wherever possible, by field experiments. The analysis of the problem, as advised in the third section above, sometimes brings to the front questions that can not be answered by direct observation, so that recourse must be had to experiment. Thus the building of the nest of *Amia* has never been observed, for the probable reason, as the observations of the writer show, that the work is done at night. In order to learn whether this work was done by the male or female, the writer introduced males into a considerable bay access to which was barred to the females by a net stretched across its mouth. By this device he learned that the nests are built by the males. In work on the breeding habits of *Lampetra* he has been able to make still more considerable use of the experimental method. There is no doubt that the use of the method may be extended to other forms.

Making of records.—Records of all observations should be made on the spot. It is not sufficient to observe what takes place and to write up notes in the evening or at some more remote convenient time. The memory can not be trusted to retain accurately the details of happenings so complicated as those that fall under the eyes of the observer of living fish. It would seem hardly necessary to insist on a precaution so obvious were it not that the observer of fish is placed under sore temptation to defer the writing of his notes. The scenes that he has before him are of absorbing interest and require his closest attention to follow them and unravel their complications. He is loth to spare any time to note taking. And not only does the taking of notes consume time; it causes the loss of observations, at least for the time being; for while the observer is recording one occurrence another follows it, and is lost to him. This loss can only be made good by repeated observation, and while the opportunity for such repetition may be long in coming, it is better to have an accurate record of a part of what has happened than to have an inaccurate record of the whole. Therefore, detailed notes should be made on the spot. There is another reason for this procedure, namely, that the writing down of an observation forces the conscientious observer to be accurate, and shows him wherein his observations are incomplete. A field note, once written, suggests some other query, so that

the writing of such notes is not merely a record of what has been seen; it is in itself a guide and a stimulus to further observation.

Field records should be not only written, but, as far as possible, pictorial also. Both sketches and photographs should be made. The technique of such work is discussed in another place in this paper. One other point needs to be insisted on here—that it is impossible to make notes in too great detail. The experienced observer is apt to find his notes doubling in volume with each succeeding year, not only because he sees more, but because he learns the wisdom of making full notes. He finds that his first year's notes leave him in painful uncertainty about many points that he feels he should have made clear. Thereafter, in succeeding years, he increases the detail of his note taking.

Compilation of observations.—A connected account should be written immediately upon completion of the field observations. The experienced field observer will go into the field with a plan of observation in mind and will proceed in accordance with this plan to work out first one part of his plan and then another. It may seem that in the field one must take things as they come and record events in the order of their occurrence, and indeed it often is desirable to do this. Yet in the experience of the writer it is in most cases better to proceed according to some plan, to analyze the problem and to take up each part of it in turn. If the observer does this, he naturally neglects for the time being those happenings that do not fall in that part of the problem that he has immediately in hand. What he thus misses at one time he must get at another. Not only are the best results obtained in this way, but events often crowd so fast one upon another that there is no other possible mode of procedure.

If now the field observer proceeds in his work in accordance with a prearranged plan, he will find it of great advantage to write a connected account of his observations at the earliest possible moment. He should do this, if possible, before the period of observation has expired. In this way he will detect gaps in his plan and will be able to fill them in; he will perhaps find the plan itself defective and be able to modify it before it is too late. If it be here objected that the writer is laying down rules which ordinarily govern the laboratory worker, and that these rules are not at all applicable in field work, he can only reply that he has applied them in field work and always with the result of obtaining better results in shorter time.

TIMES AND PLACES OF OBSERVATION.

Allusion has already been made to the fact that the breeding season offers the best opportunities for the field observation of the habits of fishes. The fish are then congregated at the breeding places, which are usually areas of shallow water; their instincts often bind them strongly to a very restricted area; they

become readily habituated to the presence of the observer. In addition to these advantages the habits of fishes are of more interest during the breeding season than at other times, and a knowledge of them is of the greatest consequence from the practical standpoint. At other seasons many fishes are in water so deep that they can not well be observed; or they are in other ways inaccessible. Nevertheless, in so far as fish are accessible outside of the breeding season, the principles that have been discussed in the preceding paragraphs may be applied.

Not only is it possible to observe the breeding habits of fishes in the field, but in the case of many species the breeding continues when the fish are confined in aquaria. In this respect there is a very great difference in species. In spite of repeated efforts I have never succeeded in observing any part of the breeding habits of dogfish (*Amia*) when the fish were under the least restraint. Dogfish that I confined in inclosures of netting on the natural spawning grounds refused to breed, even when the inclosures were 4 square rods in area. The Michigan grayling in its native waters did not breed, in the experience of the Michigan Fish Commission, when confined in a portion of the stream separated from the remainder by gratings at its ends, even when the part of the stream available for the fish was many rods in length. On the other hand, I have observed in aquaria the breeding operations of *Lampetra wilderi*, *Catostomus commersonii*, *Semotilus atromaculatus*, *Rhinichthys atronasus*, and *Eupomotis gibbosus*. It is well known that the European sticklebacks breed readily in aquaria, although I have never succeeded with our American *Eucalia*. Undoubtedly the most noteworthy work in observing the breeding habits of fish in aquaria was that of Carbonnier (1869, 1870, 1872, 1872*a*, 1874, 1875, 1876, 1876*a*, 1876*b*, 1879, 1881) at the aquarium of the Trocadero in Paris. A number of Indian, Chinese, and other exotic fishes bred there as though under no restraint.

To secure apparently normal breeding of fish in confinement the temperature of the water and the food of the fish must be regulated so as to be as nearly as possible that of the natural environment. Such regulation can be accomplished only approximately, so that the breeding habits of fishes in confinement are probably not quite normal. For this reason it is best to make observations on fish in their native waters wherever this is possible and to resort to fish in aquaria only when no other method is available, or for special purposes.

MEANS AND DEVICES FOR OBSERVATION.

Note-taking materials.—For taking notes the writer prefers the aluminum notebook covers, within which loose leaves of note paper are held by a spring. In addition to the well-known advantages of the loose-leaf system, the aluminum covers afford a hard surface for writing, and they keep the note paper from becoming crumpled in the pocket or wet by perspiration. Thus they are preferable for all sorts of field notes, but are of especial use about water, since they protect the notes from wetting. A fountain pen filled with a thin carbon ink affords a permanent and legible writing.

Field glasses.—Field glasses may with great advantage be used where the shyness of the fish precludes a too near approach of the observer. Even prism glasses (stereo-binoculars) may be used, and the writer has found those magnifying about six diameters to be admirable. Field glasses are not only often indispensable for viewing fish from a distance, but they are very useful in studying them near at hand, for then they act as magnifiers, by means of which small fish may be very considerably enlarged and the details of larger ones brought out.

Water glasses.—A very useful form of water glass is that in use on the Florida reefs. It consists of an ordinary wooden pail the bottom of which has been replaced by a circle of ordinary window glass luted into place with hard paraffin. A more convenient form of water glass for many purposes is that designed by the writer and described in his "Photography of Aquatic Animals" (1908). This is essentially a shallow box of galvanized iron into which there is cemented a bottom of plate glass. The rim of the box has an outwardly projecting lip, which lessens the slopping in of water. A bail of band iron is attached by the ends to the inside of the box in such a way that it can be folded down into the interior when not in use. Stout wires soldered across the corners of the box on the inside serve for the attachment of cords. A cover of galvanized iron fits over the plate glass on the outside and serves to protect it during transportation. The whole device is shown in figure 1, plate CXIV, with the cover at the left. This pattern the writer has used in sizes of 1, 2, 3, and 4 feet on a side. Under ordinary circumstances the water glass is allowed to float and the observer then has both hands free for taking notes or for using his field glasses. The bail serves as a means of carrying the apparatus about, and in the smaller size fits conveniently over the shoulder, so that the glass may be carried on the back, while the observer wades with both hands free. It serves the further purpose of supporting a shade of black cloth, as shown in figure 2, plate CXIV. A shade of this sort cuts off the light reflected from the sky into the eye of the observer and makes it possible for him to see much more clearly than would otherwise be possible. Where the water is so shallow that the heavy glass would sink so as to strike the bottom or interfere with the fish beneath, it may be supported on legs, as shown in figure 2. These legs are rods of iron which run through thimbles at the corners of the box and may be set at any height and held in place by thumb screws. The figure shows an observer studying the habits of the brook lamprey by the aid of such a water glass. The lampreys (*Lampetra wilderi*) were engaged in nest building and spawning beneath the glass and were not only studied but photographed by its help.

Of the various sizes of this type of water glass, that of 1 foot square is most convenient for ordinary field work where it must be carried from place to place by the observer, but this size is too small for photographic work. For this purpose the 2-foot glass shown in figure 2 is better adapted and is still not too burdensome to be carried by hand. The larger sizes are suitable only for

special uses, as on the coral reefs or where it is desired to photograph a considerable area of the bottom from a considerable distance.

The reflecting water glass designed by the writer (1909) offers some advantages over the ordinary form of water glass for certain kinds of work. It is a rectangular box of galvanized iron (fig. 3, pl. cxv), about 2 feet long and 6 inches by 8 inches at the ends, which are closed. Within the box at each end, as shown in accompanying diagram, is a mirror placed at an angle of 45 degrees with the long axis of the box and firmly fixed in a metallic setting. The reflecting surfaces of the two mirrors are parallel and directed toward each other. The box is heavily weighted with lead at one end so that when placed in water it floats in an upright position, with about 10 inches of the upper end projecting above the surface. Opposite the lower mirror in the side of the box is an opening filled by plate glass bedded in aquarium cement (fig. 3, pl. cxv). Through this window light enters from objects outside the box and these objects are reflected in the lower mirror. At the upper end of the box, on the side opposite the first window, is an opening through which the observer may look at the surface of the upper mirror, and in this mirror he sees reflected the surface of the lower mirror with the objects on the outside of the box shown in it. The observer may thus stand upright in the water, holding the water glass in front of him, and by looking into the upper mirror see submerged objects as he would see them if his head were beneath the surface. He sees the submarine landscape as it appears to a fish or to a diver through the glass window of his casque A handle soldered to either side of the box enables the operator to turn it in any direction and to hold it steady. Into the opening at the upper end of the box there may be fitted a plate of metal to which are attached two tubes lined with chamois skin and of such a size that the objective end of a pair of field glasses fit snugly into them (fig. 3, pl. cxv, right). By inserting field glasses into these tubes the observer may examine with them the objects shown in the upper mirror. Except for the limits set by the opacity of the water, fish may thus be studied from a distance as birds are studied in air. It should be added that the use of field glasses is rarely necessary with this form of apparatus, as the observer is usually

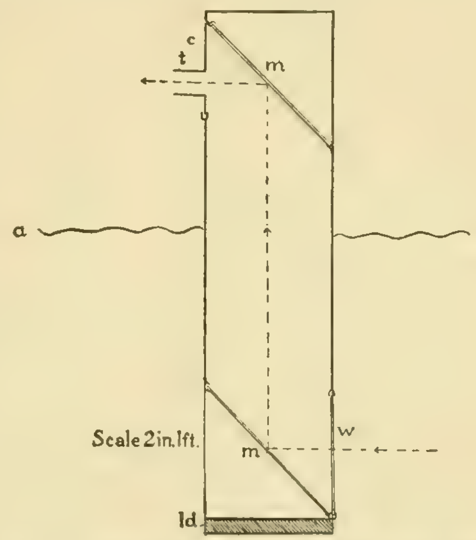

Fig. 1.—Longitudinal section of the reflecting water glass designed by the writer. *w*, Window on one side of the submerged part; *m*, mirrors; *c*, cover over the upper opening, *t*, tube for field glasses; *ld*, lead weight. The dotted line with the arrowheads shows the course of light from an external object to the eye. The line *a*—*b* represents the water's surface.

able to approach near enough for purposes of accurate observation with the naked eye. If field glasses are used the mirrors in the reflecting water glass should not be ordinary glass mirrors silvered on the back, since these produce double images which interfere to a slight extent with the working of field glasses. They should be of metal or of glass silvered on the surface, yielding a single image.

The principle of the reflecting water glass is shown in the diagrammatic figure 4, in section from the narrower side. The glass is seen entire in figure 3, plate II.

Photographic methods.—The writer has elsewhere (1908) described fully the methods which he and others have devised for the photography of aquatic animals and need here only outline these.

Photographing fish in aquaria is a method often of great value in obtaining records of their habits. The method is fully described in the papers cited in Reighard, 1908. Figure 4, plate CXV, shows the male of the common shiner (*Notropis cornutus*) with the details of scales, fin rays, and pearl organs clearly brought out. It was made with a reflecting camera from a specimen in an aquarium. Other examples of such work are figures 10 to 16, plates CXVIII, CXIX, and CXX.

Fish and fish habitats may also be photographed, by the methods already described by the author (1908), while the fish remain in their natural surroundings. To accomplish this two modes of procedure are available, as follows:

(*a*) The camera may be pointed from the air at the object beneath the surface of the water and the photograph taken through the surface of the water. In order to accomplish this it is nearly always necessary to cut off by a suitable screen the light reflected into the camera from the sky and other distant objects. This light is usually stronger than that which comes from the subject to be photographed, and if it enters the camera it affects the photographic plate in such a way as to obliterate the image formed on it by any object beneath the water's surface. One method of using such a screen and the results are shown in figure 5, plate CXVI. Here a dark screen stretched on a wooden frame is held by hand in an oblique position, so as to cut off the reflected light from the sky while allowing the full sunlight to fall on the object to be photographed. The object is in this case the nest of a small-mouth black bass. The large stones which form the bottom of the nest are shown clearly within the reflected image of the screen. Outside this image the reflected light from the sky has entered the camera so that in the picture almost nothing is visible beneath the water's surface.

Figure 6, plate CXVI, is from a photograph obtained by this method and shows brook lampreys in the act of spawning. Sometimes it is necessary to use not only a screen to cut off the reflected light, but at the same time a water

glass for the purpose of rendering the surface of the water smooth enough for a photograph to be made through it. Figure 2, plate CXIV, shows such a combination of water glass and screen as used for photographing the lampreys of figure 6. The broad white bands in figure 6 are the edges of the water glass. It is to be noted that within these bands the picture is clear while outside them it is not clear. The lack of clearness in that part which lies outside the borders of the water glass is due to the running water, which is there much disturbed, as shown in figure 2, plate CXIV.

(*b*) The second method of photographing objects beneath water in their natural environment is to inclose the camera in a water-tight box and immerse this, and for this purpose a reflecting camera should be used. The principle of such an instrument is illustrated in the accompanying figure, which shows it in longitudinal section. The light entering the camera is reflected by a mirror, *m*, to a ground glass, *gl*, in the top of the camera and the image formed by it is viewed by the photographer as he looks down through the hood, *hh'*, on top of the camera. This image is of full size, and owing to the action of the mirror is erect. While looking at it the operator may focus the camera and thus keep the image always sharp, no matter how much the object may move. The mirror is hinged at its upper edge at *x*, and the operator can, by pressing a release button, cause it to swing upward until it reaches the position *m'*. It then covers the lower surface of the ground glass in such a way as to prevent the entrance of light through it. The light, hitherto reflected upward from the mirror, now passes backward and may form an image on the sensitive plate, *p*. In front of the sensitive plate there is a shutter, *s*, of the focal-plane type. This is essentially a roller shade of black cloth which may be wound on an upper roller, *r*, and made, by the action of a spring, to unwind very rapidly from the upper roller and wind on a lower roller, *r'*. In passing from one roller to the other the curtain passes in front of the plate. In one place in the curtain is a transverse slot and through this the light falls upon the sensitive plate as the slot, *sl*,

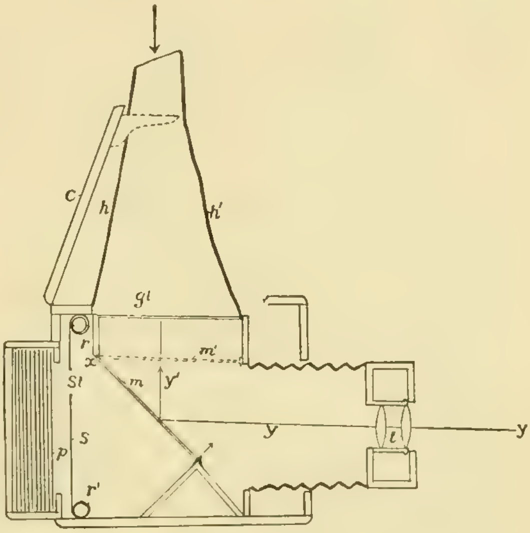

FIG. 2.—A reflecting camera shown in section, with magazine plate holder attached. *gl*, Ground glass. *h h'*, hood. *l*, lens; *m*, mirror in position during focusing; *m'*, mirror, showing position during exposure; *p*, sensitive plate; *r* and *r'*, rollers of focal plane shutter. *s*, the shutter; *sl*, slot in shutter. *x*, hinge on which mirror turns; *y y y'*, ray of light traversing the lens and reflecting from the mirror to the ground glass.

passes across its face. The rate at which the curtain moves and the width of the slot may be regulated. When the operator with the mirror set at *m* has focused the object and brought it into the desired position on the ground glass, he presses the button which releases the mirror. At the instant the mirror reaches the position *m'* it releases the mechanism which actuates the shutter, and the roller with its slot travels across the face of the plate, so that the exposure is made. It is unnecessary to dwell here on all the advantages of this form of camera. The feature of importance is that the camera permits the object to be kept in focus up to the instant of exposure and then permits the exposure to be made without removing the ground glass and inserting the plate, as is necessary in the ordinary form of camera.

In using this form of camera for photographing objects under water the writer inclosed it in a water-tight box of galvanized iron. This box, shown in figure 7, plate CXVII, is provided at one end with a plate glass through which the picture is taken. In the top of the pyramidal portion of the box which covers the hood of the camera there is a second plate of glass which does not show in the figure and through which the operator looks into the hood of the camera and examines the image on the ground glass. The camera is focused from the outside with the right hand by means of a milled head, from which a stem extends through a water-tight stuffing box to connect with the focusing screw of the camera. The exposure is made by pressing a pin which is on the opposite side of the box from the milled head shown in the figure and which also extends through a stuffing box to the interior of the water-tight box, where it actuates the mechanism by which the mirror of the camera is set in motion. The top of the box is held in place against a rubber gasket by eight thumbscrews by the use of which the joint between the box and the lid is rendered water-tight. When the box is in use its bottom must be heavily weighted with lead to submerge it.

In figure 8, plate CXVII, is shown the method of using the reflecting camera when inclosed in the water-tight box. The photographer is wading near a coral reef. The body of the box inclosing the camera is submerged, but the pyramidal top of the box inclosing the hood of the camera projects above the surface of the water. Through the glass in the top of the hood the photographer is viewing the image on the ground glass, while he focuses the camera with the right hand and is prepared to make the exposure with the left hand. When the exposure has been made the water-tight box must be taken from the water and opened in order to change the plate before making a second exposure.

If the water-tight box is made strong enough to resist the pressure of the water the photographer may descend in a diver's suit and may, with the apparatus described, make photographs at considerable depths. If the camera box is set on a tripod time exposures may be made with an apparatus of this type, but

some changes would then be necessary in the mechanism by which the shutter is operated from the outside of the water-tight box.

II. ILLUSTRATIVE EXAMPLE OF METHODS OF OBSERVATION.

BREEDING HABITS OF THE HORNED DACE (*Semotilus atromaculatus*).

In the selection of the horned dace, rather than commercial or otherwise more important fishes, to illustrate the present discussion, chiefly two considerations have controlled: (1) That the matter here presented has not hitherto been published, and (2) that the behavior of the horned dace is so complicated that it affords an excellent illustration of the methods the writer has found successful in the study of the behavior of fishes in the field. The horned dace is, however, not without economic importance. It is sometimes eaten, but its chief value lies in the fact that, more than any other fish in the region in which it occurs, it furnishes bait to the angler. The present account of its breeding habits embodies the results of the observations of many years, or rather of many seasons, but the record is not a final one. It is an outline or sketch, a preliminary account from which details are purposely excluded.

There is no published description of the breeding habits of the horned dace, although its conspicuous nests must often have been observed. Kendall and Goldsborough (1908) publish notes prepared by Superintendent Charles G. Atkins, of the United States Bureau of Fisheries Station at Craig Brook, Maine, on the breeding habits of *Semotilus bullaris*. They report that they have themselves seen the nests of this form and give a diagrammatic picture of such a nest with the fish on it. More detailed observations are greatly to be desired, especially since the nest-building behavior described for *Semotilus bullaris* appears to be intermediate between that described in this paper for *Semotilus atromaculatus* and that observed by the writer in *Hybopsis kentuckiensis* and not yet published.

Observing the fish at nest-building time.—The observer who approaches one of the gravelly brooks of southern Michigan during the latter part of April or in May is likely to have his attention attracted by certain elongated heaps of gravel scattered at intervals along the bottom of the stream (fig. 9, pl. CXVIII, and fig. 3, text). These catch the eye, because the stones that compose them are clean, as though scoured, and show their blotches of bright colors. The heaps consequently stand out in sharp contrast to the surrounding bottom, which is everywhere covered with a uniform brown ooze. Each of these heaps has the form of a low, rounded ridge, commonly a foot in width and 2 or 3 inches high, but varying in length from a foot to 16 or 18 feet. The ridges run with the stream, and at the downstream end of each is an oval pit (*P.*) 2 or 3 inches deep and as wide as the ridge. Below the pit again is seen a trail of clean sand, which at its begin-

ning is as wide as the pit, but as it is followed downstream gradually narrows to a point (*S. T.*, in fig. 9, pl. CXVIII, and fig. 3, text).

As the observer approaches one of these structures he may see the flash of a fish departing from the pit, and he is then apt to move on in the belief that nothing more is to be seen. But if he lies prone on the bank and keeps perfectly still the fish will return. This may happen after ten or fifteen minutes, or it may not happen for an hour, and during all this time the observer must remain motionless, not moving so much as a hand or foot, for if he moves the fish at once flees to shelter and does not reappear for some time. It again departs if the movement is repeated, but each absence is shorter than the preceding, and after a time, if the movements are not too abrupt, the fish remains on the nest in spite of them. For him the observer has become a part

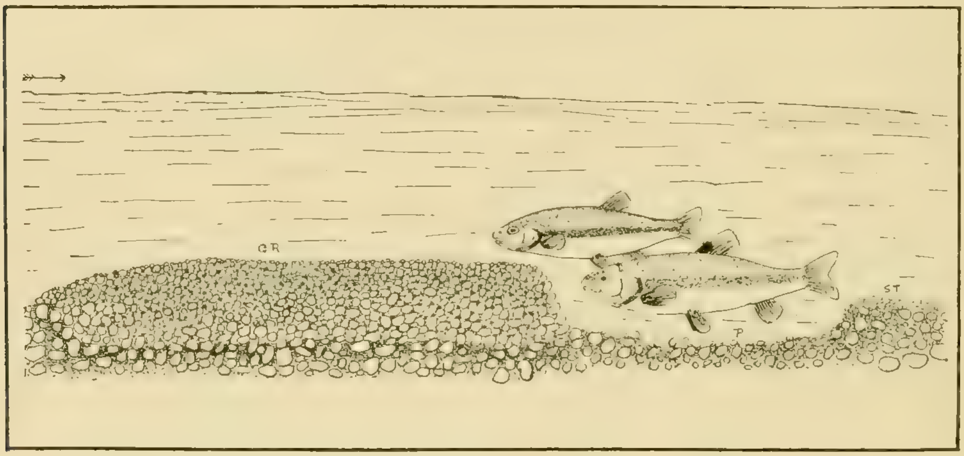

FIG. 3.—Showing in longitudinal section the nest of a horned dace with the male and female fish on the nest. The stream flows in the direction indicated by the arrow at the upper left corner of the figure.

of the landscape, to which he pays no more attention than to a tree. The fish that returns (fig. 10, pl. CXVIII) is usually 8 or 10 inches long, of a beautiful apple-green color above and of a rose red below. If a small fish, there may be a stripe of dark brown between the two colors, where they join along the middle of his side. At the base of the dorsal fin in front is a black spot (fig. 12, 13, pl. CXIX), and above this an orange spot, while the caudal and paired fins are yellow. If the observer is very near, or if he uses field glasses, he may see along the sides of the head above the eye and nostril a row of 4 or 5 white horn-like spines (fig. 10, pl. CXVIII, and text fig. 5, p. 1130). These are pearl organs, so called because in some related forms they have the rounded glistening look of pearls (see fig. 4, pl. CXV, on the snout). By them and by its colors the observer may recognize the fish as the male of the horned dace.

The nest-building process.—Presently the fish will be seen to put its head to the bottom of the pit and by vigorous movements of its tail appears to try to force its way into the bottom, as in figure 11, plate CXIX, in which it is seen to have seized a pebble. Presently it rights itself and is then seen to have picked up a good-sized stone from the bottom of the pit (fig. 12, pl. CXIX). With this it swims to the lower end of the ridge of gravel and there drops it (fig. 13, pl. CXIX), so that it falls on the end of the ridge or rolls down into the pit. In either case it helps to lengthen the ridge. Sometimes a stone too large to be taken into the mouth is pushed along the bottom (fig. 14, pl. CXIX). The fish now carries stone after stone in this way until the ridge is visibly lengthened. Sometimes instead of a single larger pebble the fish takes into its mouth a mass of smaller pebbles, with a considerable amount of sand. When this happens, he does not drop his burden on the end of the ridge, so as to lengthen it, but proceeds some little distance farther upstream, until his head at least is well above the ridge. Then with a movement of his head first to one side and then to the other he distributes the mouthful of small pebbles over the top of the ridge, so as to form a top dressing. As the pebbles leave his mouth it may be seen that the sand which was taken up with them is washed downstream and falls to the bottom below the nest, where it forms the trail already seen (fig. 4, text, at right). This trail is added to by the sand stirred from the bottom of the pit by the fish whenever he picks up a stone. As the ridge lengthens it slowly encroaches on the pit and tends to fill it. But as this occurs at the upper end of the pit the fish slowly pushes his excavation downstream, lengthening the pit at the lower end, so that it does not become filled. The whole ridge thus lies in a long trench, which has been excavated as the fish slowly drops downstream and has been filled by the ridge as fast as made. Only the pit in which the fish lies has been left unfilled at the lower end of the ridge. If the observer is fortunate enough to arrive as the dace is beginning its nest, he may see it dig a little pit in the level bottom and pile the stones on its upstream edge (fig. 13, pl. CXIX). By gradually lengthening this pit and at the same time filling it he completes his nest.

The structure of the completed nest is shown in perspective in figure 9, plate CXVIII, and as it appears in longitudinal section in the diagrammatic figure 3, page 1126. At the right of text figure 4, page 1128, it appears in plan. The bottom of the stream is here composed of gravel, with sand intervening between the stones. In this the long trench has been excavated and partly filled with the stones that have been removed in digging it. These stones may be distinguished from those that still remain undisturbed in the bottom by the fact that they are clean and the sand has been washed from between them. They form a low ridge, which projects from the trench somewhat above the

level of the bottom. The unfilled part of the trench—the pit in which the fish are seen—lies at the lower end of the ridge. The sand washed by the current from between the stones that have been moved in making the ridge collects in a trail below the pit and is seen there in the figures.

As the fish continues to work at the nest the observer may slowly, very slowly, raise himself into a sitting position, and if he is careful the fish will not be frightened by this. Then, after a time—a half hour, perhaps—he may slowly rise to his feet, and in the course of time may slowly approach the nest until he is within 8 or 10 feet of it. How much of this he may do and how rapidly he may do any of it can only be learned by trial in each case, for it depends on the individuality of the fish and upon the particular stage of his activities. To the fish the relatively immobile observer becomes, after a time, a part of the landscape and no attention is then paid to him.

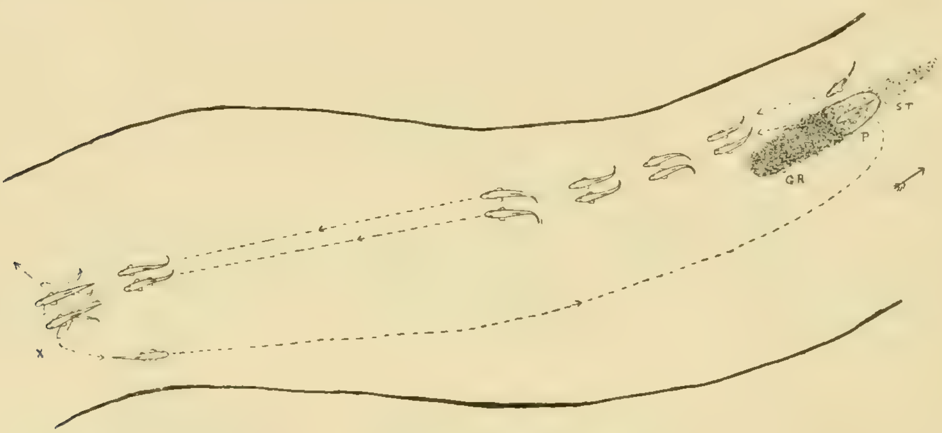

FIG. 4.—Showing the ceremonial behavior of the horned dace when a strange dace approaches the nest. The owner of the nest is seen in the pit, *P*. Above this is the gravel ridge, *G. R.*, and below it is the sand trail, *S. T.* The direction of the current is indicated by the arrow at the right. The course of the two fish upstream to the point *X* and the return of the owner to his nest are indicated by the broken lines with the arrowheads. The heavy lines indicate the banks of the stream.

Protection of the nest against other fishes.—Other fish approach from time to time as the dace works at his nest. Minnows of other species frequently attempt to enter, but if smaller than the dace they are pursued and driven out. Frequently other male dace approach the nest. If these are smaller than the nest builder they are pursued and then invariably flee. Such small males are distinguished from the larger ones by the presence of a dark lateral stripe (fig. 11 to 16, pl. CXIX and CXX). If the male dace that approaches the nest is of the same size as the nest occupant a battle frequently ensues. The two strike at each other with their heads in apparent efforts to inflict wounds with the sharp pearl organs. They often struggle together fiercely in these encounters, but neither fish appears to suffer any injury. The sole result seems

to be to produce temporary discomfort in the fish that is hooked, and this usually results in the departure of the intruder.

The attempt of a male to appropriate the nest of another fish of equal size does not always result in an encounter. Frequently it happens that as the strange male approaches the nest the occupant ranges himself alongside and the two fish swim upstream with great deliberation for a distance of 15 or 20 feet (text fig. 4). In their course they move slowly and swing their tails from side to side in unison, as though keeping step with them. At the end of their course they settle to the bottom and bring their heads together gently, as though bowing to one another. They then usually separate their heads and bring their tails together, as though about to swim away from one another. They then commonly again bring their heads together and finally separate, the owner to return to his nest, his companion to some near-by shelter. This performance, which with some variation is so often seen that it must be regarded as a part of the normal behavior, may be interpreted as a deferred combat. The two fish move along side by side, like two boys threatening each other but each afraid to strike. When they have gone a certain distance they approach each other and make certain threatening movements in unison and then they separate. This mode of behavior, which has the appearance of a ceremonial, is illustrated diagrammatically in text figure 4, where the nest is seen from above with its owner in the pit. The outlines of the stream are represented by the heavy black lines, while the direction of the current is indicated by the large arrows. The nest shows the gravel ridge, the pit at its lower end, and the sand trail below the pit. The movements of the two fish in their upstream course, as well as after they have stopped, and the return of the owner to the nest, are represented by the successive outlines, and their direction is indicated by arrowheads.

Spawning behavior of male and female.—While the male dace is building his nest the females are waiting in some near-by shelter. At any time during the progress of the nest building they may be seen to approach the nest, usually one at a time, but sometimes in troops of three or four. The females may be distinguished from the males by their smaller size (fig. 10, pl. CXVIII), for while they may be as long as the males they are nearly always smaller and frequently not more than one-fourth as long. They are further distinguished by the absence of the bright colors on the body and of the black and orange spots in the dorsal, as well as by the absence of pearl organs. From larger males they are distinguished by the presence of the lateral stripe. In all these respects they resemble young males, but from these they may be told after a little practice by the fact that their abdomens are distended with eggs (fig. 10). As a female approaches the nest for the first time the male turns toward her and she then usually flees without actually entering the nest. Presently she returns, again

approaches the nest and comes a little nearer, but again flees as the male turns toward her. As female after female thus approaches the nest their coyness gradually diminishes, until one, bolder than the rest, enters and does not flee as the male approaches. She gives no assistance in building, for that is the work of the male. As she enters the nest the male first turns toward her and then, as she comes nearer, takes up his position at the bottom of the pit at the lower end of the gravel ridge, as shown in figure 3, page 1126. He lies usually nearer the bottom of the pit than shown in the figure and often turned somewhat on one side, and in this position he waits until the female has taken a position just above him or at his side. Even when the female has come so far she often again flees, and in that case is pursued by the male, who attempts to bite or hook her. Usually when she has come near enough the male gets his head and his expanded pectoral fin of one side beneath her, and then with a movement often too rapid to be followed by the eye he tosses her into an upright position and at the same time encircles her body with his own. When this has happened the two fish are in the position shown in figure 15, plate CXX, and text figure 5, page 1130. Then the male immediately straightens his body and releases the female. The length of time required for the male to clasp and release the female varies, but is always very brief. It appears to take about as long as is required to close and open the hand when that movement is performed as rapidly as possible. This seems to be usually one-tenth of a second, but is often more.

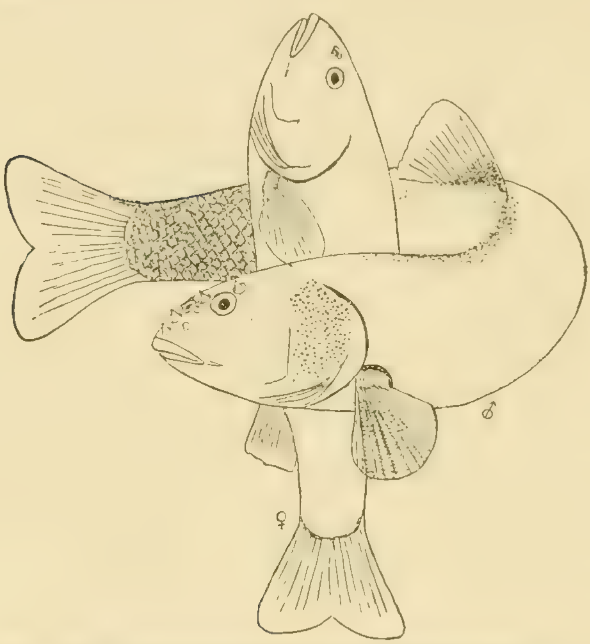

FIG. 5.—Male and female horned dace during the spawning act. On the male, which is the fish with the body curved, are shown above the eye and in line with the nostril, four spine-like pearl organs and below these two smaller spines. Small organs are seen on the operculum and dorsal surface of the pectoral fin and on the caudal edges of the scales on the tail.

When the two fish are in the position shown in text figure 5, the surface of the opercle of the male is seen to be pressed against one side of the female, while the side of his body back of the dorsal fin is pressed against her other side. At the same time the upper surface of his pectoral fin of one side is

pressed against her ventral surface. The female always has her head up and her tail down as shown in the figure, but the positions of her dorsal and ventral surfaces with reference to the body of the male may be the reverse of that shown. The movements of the fish are so rapid that it requires many observations on each part of each fish before the observer can be sure of accuracy.

A close examination of a breeding male of the dace is necessary to show the means by which he retains his brief hold of the female in spite of the slipperiness of the skin of both fishes. If he be so examined, it is found that those parts of his body which are in contact with the body of the female during the embrace are beset with minute, sharp pearl organs, and are thereby rendered rough, like a piece of sandpaper (fig. 5, text). The opercular region, covered with close-set pearl organs, has a shagreen-like feel. The sides of the body and tail from the caudal edge of the dorsal fin backward are provided with minute organs which occur in rows along the slightly everted edges of the scales and roughen the surface over which they are found. Finally the upper surfaces of the pectoral fins are provided with close-set organs of moderate size which form rows along the fin rays. By means of these organs the male, whose body would otherwise be smooth and slippery, is enabled to make effective his brief hold of the female. This is the more necessary to him since his scales are devoid of the tooth-like points which occur along the free edges of the scales (ctenoid scales) of many fishes and render their bodies rough to the hand.

While the female is held in the embrace of the male she emits a few eggs, and with field glasses these may often be seen falling slowly through the water until they rest on the gently sloping end of the gravel ridge or on the adjacent bottom of the pit. Probably not more than 25 to 50 eggs are emitted at one time. The released female then floats for a moment belly up as though dead, while the male appears to examine the falling eggs. (Fig. 16, pl, CXX.) The female now speedily recovers and disappears along the neighboring bank, but after a short time returns to the nest and repeats the spawning. She continues this intermittent egg laying until all her eggs have been deposited. She may thus place her eggs in one nest, but more often she deposits a part of them in one nest and a part in another. Meantime, during her absences, other females have entered the nest and laid their eggs, so that when the eggs of any nest are examined they are found to be of several different sizes corresponding to females of different sizes that have entered the nest.

When the females are not in the nest the male continues to carry stones and thus lengthens the gravel ridge. The eggs that have fallen on the end of the ridge or into the pit just at its base are thus covered by the added stones and included in the ridge. As one female succeeds another and as the gravel

ridge at the same time lengthens, it becomes filled with eggs. The position of these eggs is shown in figure 3, page 1126, by the black dots among the stones of the gravel ridge. The eggs are undoubtedly fertilized at the moment they are laid, but owing to the fact that the seminal fluid of the male is colorless its emission can not be observed.

Security of nest structure.—The structure of the nest (fig. 3, p. 1126) is such as to afford the eggs protection, for, as already pointed out, the base of it is composed chiefly of larger stones, which the male drops directly on the end of the ridge, so that they roll down toward its bottom. Among these larger stones the eggs are lodged. The surface of the ridge is, on the other hand, composed chiefly of smaller pebbles which there fill the chinks between the larger stones. By this arrangement the eggs in the spaces between the larger stones in the base of the ridge are separated from the free water above by the fine gravel which closes these spaces at the top and are thus protected.

When the nest of the horned dace has been completed it is a conspicuous object on the bottom of the stream, because the pebbles that compose it are clean and stand out in sharp contrast to the ooze-covered pebbles of the surrounding bottom. But within a very few days the sediment from the stream covers the nest pebbles also and the nest becomes then almost indistinguishable. Meantime the builder of the nest, now that his breeding ardor has run its course, has abandoned his work, and the nest with its contained eggs is left to its fate. Here the eggs undergo their development, and after a time, which varies with the temperature of the water, the young fish hatch from them. The eggs or the newly hatched fish may be obtained at any time by scooping up a part of the nest gravel and agitating it with water, when the eggs, which float for a moment in the agitated water, may be poured off. The newly hatched dace do not differ greatly in their general features from the adult, but no accurate description of them has been made. How long they remain in the nest is not known, nor has their method of exit from it been observed. They must soon make their way out through the spaces between the pebbles and through the overlying ooze, but the precise time and method of accomplishing this are not known. Very small dace and those of every intervening size up to the adult are found in the same streams with the parent fish and differ from them apparently only in the smaller size of the prey which they capture and in occupying a slightly different habitat.

The nest of the dace affords an absolute protection of its eggs and young against the smaller carnivorous fishes, and this protection arises from two sources. The presence of the male dace on the nest keeps these little enemies at bay while the eggs are being laid and while they are being covered by pebbles. This protection extends over some days at least. Besides this the covering of stones over the eggs effectually excludes small fish after the male dace has left the nest.

At the same time the top covering of small stones filters out much of the sediment which would otherwise sift down upon the eggs and smother them or carry to them the fatal spores of fungus.

The horned dace and the other minnows that build stone nests are relatively small fish, toothless, and without spiny fin rays, so that they have no effective means of repelling the attacks of their enemies. They would therefore be unable to protect their eggs by guarding them in open nests after the manner of the larger and more formidable fresh-water dogfish and black bass. By building stone nests which inclose and protect their eggs, certain of these minnows, including the horned dace, seem to have followed the most effective method open to fish which are physically incapable of personally defending their offspring.

Destructive agencies.—Yet the nests of the horned dace are not impregnable castles. Against the smaller carnivorous fishes they afford ample protection, for the stones of which they are built are too heavy to be moved by *Rhinichthys*, *Pimephales*, *Etheostoma*, and the like. On the other hand, the nests may easily be disturbed and even robbed by larger fishes. *Campostoma* and *Catostomus* habitually uproot small stones in the process of feeding, and it is possible that in this way they uncover and devour the eggs of the horned dace, though I have not observed this. But there is another way in which the structures built by the horned dace are frequently torn to pieces and their contained eggs probably devoured, and that is by the nest-building operations of other fish. When a horned dace nest has been completed by its builder and abandoned, a second dace frequently selects the same site for his nest and proceeds to build with the materials used by his predecessor. Or a *Campostoma* may use the gravel ridge of a horned dace nest as a suitable place in which to excavate his pit, or a *Hybopsis* may carry away some of the dace materials in building his nest. These fish all build at about the same time, and their pits, ridges, and stone piles occur on the same areas. By this process of the repeated occupation of the same area by other fish of the same and other species, the nests of the horned dace are often disturbed, and in such cases the contained eggs are probably in part destroyed. The extent to which this happens varies in different streams. In certain streams areas which I have kept under observation have been utilized as nesting sites two or three times in succession, and the first dace nests built in them have been thereby wholly or in part destroyed. In other streams most of the dace nests have been left undisturbed. Again the top dressing of fine gravel by no means suffices to exclude all sediment. Sediment and fungus spores reach the eggs. In many of the nests that I have examined, living eggs were found in the new-built parts, while the older parts contained only dead eggs matted together and covered by fungus.

SUMMARY OF OBSERVATIONS OF THE BREEDING HABITS OF THE HORNED DACE.

1. The horned dace breeds in southern Michigan from late April to early July.

2. Breeding males are distinguished from females by their larger size, brighter colors, the presence of pearl organs, and abdomen not distended as in the female.

3. The breeding takes place in clear streams, which vary in width from 1 or 2 feet to 4 or 5 rods, on bottom of coarse gravel, and usually at the heads of rapids.

4. The male fish builds nests without assistance from the females.

5. The nests are constructed, each chiefly by an individual male, by picking up and carrying stones in the mouth.

6. Each male thus excavates, parallel to the course of the stream, a long trench, usually a foot wide and 2 or 3 inches deep, but varying in length from 1 to 16 or 18 feet.

7. As he excavates this trench he fills it with the gravel removed in making it, so as to form a ridge of gravel which extends 2 or 3 inches above the top of the trench.

8. The trench and ridge are extended downstream, and the fish always occupies the unfilled portion of the trench at the lower end of the ridge. This I have called the pit.

9. The sand washed from between the stones in moving them accumulates in a trail below the pit.

10. In forming the ridge most of the coarser gravel is deposited so as to form its base, while the finer gravel is used chiefly as a top dressing on the surface of the ridge.

11. The male guards the completed nest, and often defends it by giving battle to other males.

12. Frequently when the nest of one fish is approached by another male dace of equal size there ensues, not a combat but a "ceremonial" which may be interpreted as a deferred combat.

13. The females may enter the nest and lay their eggs at any time during the process of nest building, and the eggs thus laid are covered in the subsequent operations of the male. Consequently they are included in the gravel ridge and this ridge is filled with the eggs of many females.

14. When a female enters the nest to spawn, she is thrown by the male into a vertical position and encircled by his body; in this spawning attitude the head of the female is always up and the opercle and pectoral fin of the male are pressed against one of her sides while his tail behind the dorsal fin is pressed against her other side.

15. The embrace of the female by the male lasts for a fraction of a second, during which a small number (probably 25 to 50) eggs are laid and fertilized.

16. The female when released usually floats belly up for a moment, and in all cases leaves the nest. She subsequently returns many times to the same nest, or enters another nest, and on each occasion deposits a small number of eggs. This continues until her eggs, laid in one nest or several, are all deposited.

17. The sharp pearl organs on the head of the male are used as weapons, while the smaller organs on his operculum and on the sides of his tail, together with those on the dorsal surface of his pectoral fin, are used in retaining his grasp of the female during the act of spawning.

18. When the male has completed his nest he deserts it, and it rapidly becomes covered with silt and not easily distinguished from the surrounding bottom.

19. The eggs hatch within the nest, and the young make their way out through the chinks between the stones.

20. The nests of the horned dace are of advantage to the species in affording protection to the eggs against sediment and against the attacks of the smaller carnivorous fishes.

21. The nests of the horned dace are often destroyed by the nest-building activities of other dace and of other species of larger minnows (*Campostoma anomalum*, *Hybopsis kentuckiensis*), and the eggs are frequently attacked by fungus.

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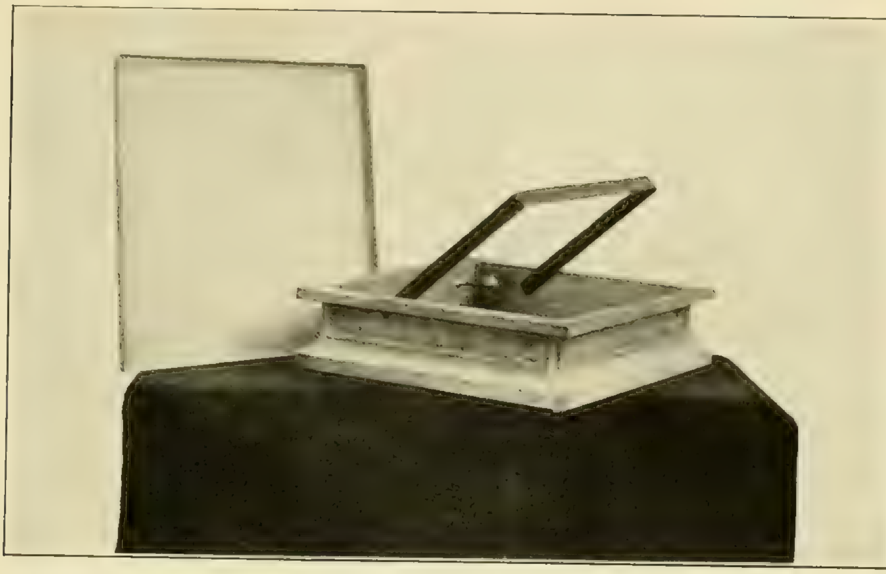

FIG. 1.—Water glass designed by the writer to be used for observation or photography of objects under water. The cover is shown at the left.

FIG. 2.—Two-foot water glass supported on four legs and provided with screen, as used for studying and photographing lampreys (*Lampetra wilderi*).

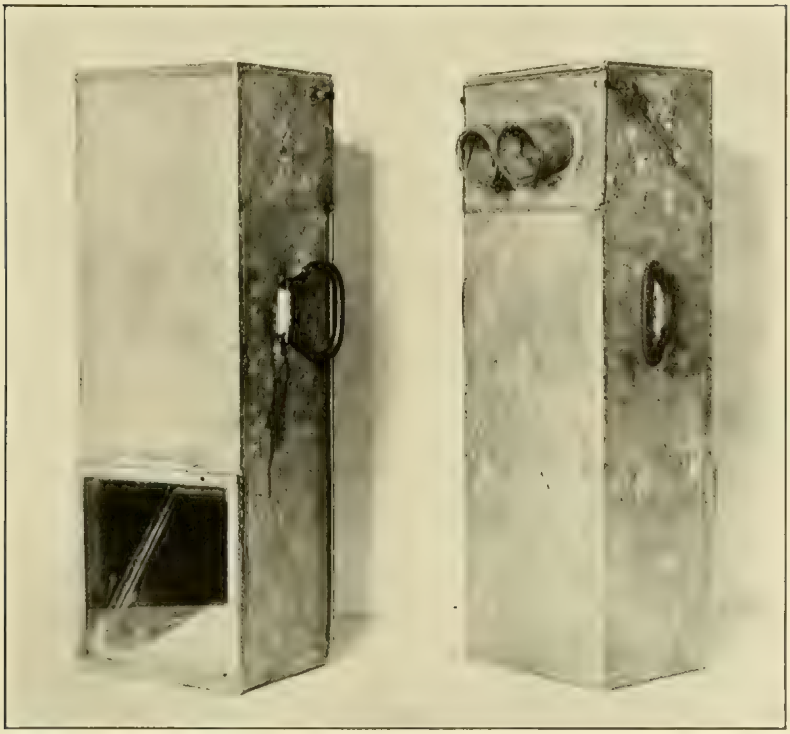

FIG. 3.—Reflecting water glass used by the writer. For description see text. Compare figure 4, text.

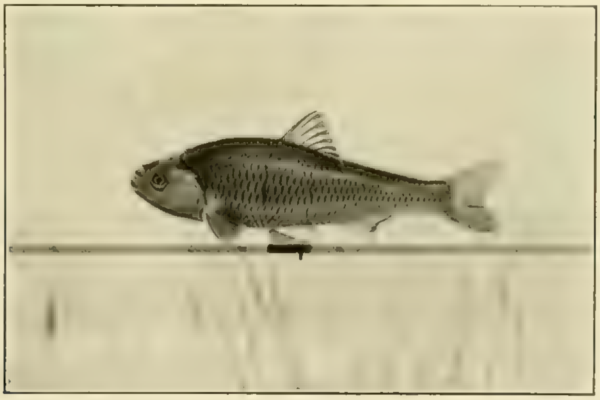

FIG. 4.—Male of the common shiner (*Notropis cornutus*), photographed in an aquarium out of doors with a reflecting camera.

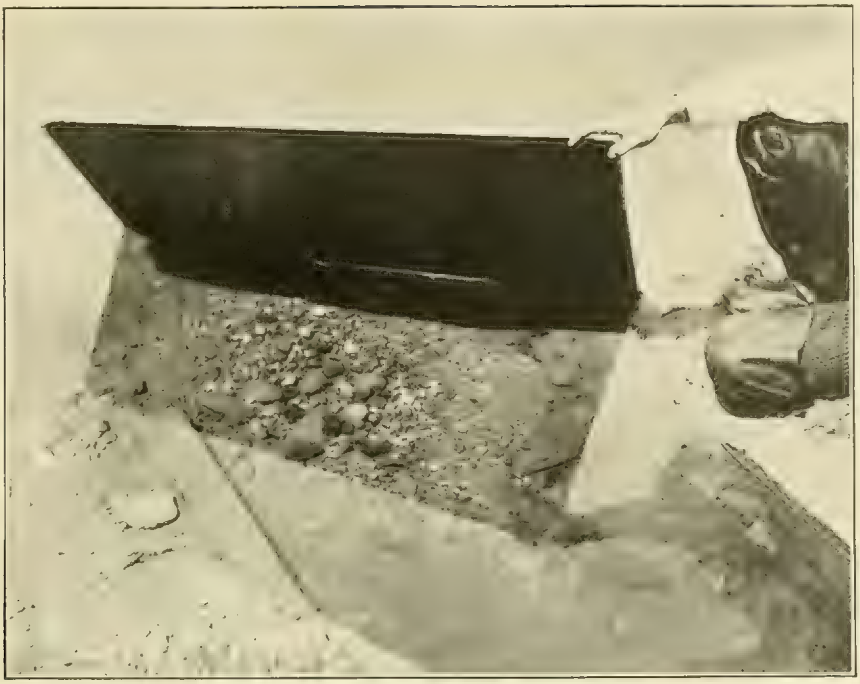

FIG. 5.—Photograph of the nest of a small-mouthed black bass (*Micropterus dolomieu*) taken with the aid of a screen, the camera above water

FIG. 6.—Brook lampreys (*Lampetra wilderi*) on the nest, photographed through the water glass shown in figure 2, plate CXIV, in about 8 inches of running water.

Fig. 7.—Galvanized-iron box with plate-glass front, designed by the writer to contain a 5 by 7 reflecting camera for use under water.

Fig. 8.—Photograph showing the method of using the reflecting camera inclosed in the water-tight box for subaquatic work. The upper part of the box covering the hood rises above the surface, while the lower part, containing the camera proper, is under water. The operator is looking into the hood through the plate glass in the top of the box. With his right hand he focuses, with his left makes the exposure.

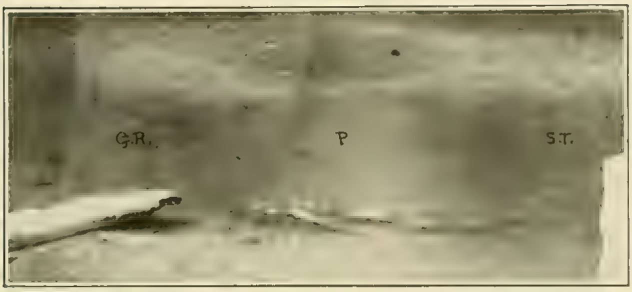

FIG. 9.—Photograph of the nest of a horned dace (*Semotilus atromaculatus*), taken with a reflecting camera and by the aid of a cloth screen used as shown in figure 6, plate CXVI. The reflected image of part of the screen is seen over the right and left parts of the nest. In the upper part of the picture at the right above *S. T.* is the sand trail; to the left of this, above *P.*, is the pit, in the bottom of which are large pebbles; farther to the left, above *G.R.*, is the gravel ridge with its top dressing of fine pebbles. The end of the ridge, its structure of coarse pebbles, is within the pit at the left.

FIG. 10.—Male and two females of the horned dace (*Semotilus atromaculatus*). One female is above at the left, the other behind the male. The head of the male bears four pearl organs. Photographed with a reflecting camera, the fish in an aquarium out of doors.

FIG. 11.—Male horned dace picking up a stone. His lips are grasping it.

FIG. 12.—Male horned dace about to drop a stone which he carries in his mouth.

FIG. 13.—Male horned dace which has just dropped a stone, but has his mouth still open.

FIG. 14.—Male horned dace pushing along the bottom a stone too big to carry.

FIG. 15.—Photograph of dace in the act of spawning. The female is in the upright position. The male has either not completed his embrace of the female or has just relaxed it. Photograph made with a reflecting camera, the fish in an aquarium out of doors.

FIG. 16.—Male and female of the horned dace just after completion of the spawning act. The female floats belly up as though dead. The male appears to examine the falling eggs, which are in front of his head and in front of the stones beneath him as well as in the intervening clear water. Photograph made with a reflecting camera, fish in an aquarium out of doors. The vegetation shown in this and the other figures was painted on the back of the aquarium.

A METHOD OF STUDYING THE LIFE HISTORY OF FISHES

By Charles F. Holder

Paper presented before the Fourth International Fishery Congress
held at Washington, U. S. A., September 22 to 26, 1908

A METHOD OF STUDYING THE LIFE HISTORY OF FISHES.

By CHARLES F. HOLDER.

The owners of the island of Santa Catalina, Cal., latitude 33°, at my suggestion established a small zoological station, which was thrown open free to students who would come with letters from teachers. The aquarium cost about $10,000. The tanks were placed out in the room so that they could be examined from all sides and the light reach all parts. For all purposes this plan is the most satisfactory, though it does lose the glamor of the "dark, unfathomed caves," which, as often seen in aquariums, are unnatural. Nearly all fishes that live near the surface like the sunlight as it sifts down through the water, so in the zoological station the tanks are bright and clear, and the fishes can be seen, slightly magnified, from all sides, and studied or admired.

No better opportunity to study the life history of fishes can be imagined, and as the fauna resembles that of the Bay of Naples, or, if possible, is richer, the field is an interesting one and almost totally missed by zoologists who take tables at Naples, paying for them, when they could have a greater opportunity here for nothing. Through the courtesy of the owners I have had the entrée to this aquarium and have made many interesting observations.

In observing the habits of fishes I have taken, for example, the shiner, a surf fish, keeping it before me constantly. During the breeding season I observed the birth, which was tail first, of the remarkably large young, and had them before me until they reached the adult stage. The development of the Garibaldi was more interesting, as it is at first a beautiful metallic blue, iridescent, and gradually, as it grows, assumes an orange-red tint, until when nearly 2 years old it is almost entirely orange. I watched the changes, kept the fish in different tanks, and tried them with different foods and colors. I had a tank built about 3 feet long, 8 inches wide, and 2 feet high, which I used in photographing fishes at different ages and stages of their development. The tank could be arranged with the weed in which the fish live in a state of nature, and was placed on the roof of the aquarium in the sun. It was so narrow that the prisoners could not get away from the camera, hence were easily photo-

graphed. I have a series of nearly all the fishes of this region, and I commend this method of individual tanks for old and young fish and eggs, and the photographing of them at intervals, as a simple yet conclusive method of examination and study.

From the side of the tank every motion of a fish could be observed, while in an adjoining room were specimens of the same fish in alcohol or formalin for study. Here I saw the swell shark and the California Port Jackson shark deposit their eggs; later I saw the young making their way out of the corkscrew eggs, then had them photographed as they were hatched, the entire history of the fish being observed and recorded.

I paid particular attention to the protective resemblances. I arranged tanks with colored bottoms and watched and timed the adaptation of color in sculpins and the beautiful kelpfish. In the latter is found one of the most beautiful of all fishes that depend upon protective resemblance. It not only imitates the kelp perfectly in tone, shade, and color, but hangs in it, head down, imitating the leaf in shape and position. I followed the fish from birth to the laying of eggs; found that the female was nearly twice as large as the male, and I think I had the first opportunity to notice the building of the nest, which I reported to the American Naturalist. The male had glorious nuptial colors. I watched the female carefully, and the moment she sank to the bottom, exhausted from an effort of twining a silken egg cord about the weed, the male sprang ahead, poised over the eggs, his body violently quivering as he showered over them a cloud of spermatozoa. The following is an account I published in the American Naturalist:

One of the most interesting fishes found in the great kelp beds along the shores of Southern California is the so-called kelpfish, *Heterostichus rostrata* Girard. In color it closely resembles the seaweed in which it habitually lives. During the past year two adult kelpfishes and a smaller fish of another kind occupied one of the tanks in the Santa Catalina Island Aquarium. The larger kelpfish, a female, was about 9 inches in length; the male measured about 5 inches. I was attracted to them by the savage attacks of the male on a stranger, and investigation showed that he was in nuptial colors and was attending the female. The offending fish was removed, giving the kelpfish the entire tank.

All the colors of the male kelpfish were highly accentuated and brilliant. What had been white was now lavender and silver; the dark angles of the zigzag barring took on darker tints and were emphasized by countless lines of lavender, yellow, blue, and gold; patches of silver, old rose, lavender, and white appeared here and there the entire length of the fish, making it a most gorgeous creature. The long vibrating dorsal fin was erect, and the fish was unusually alert as if sensible of the importance of the situation and its responsibilities.

In the tank were several small bunches of a deep maroon seaweed 4 or 5 inches high; and as I watched the female, large and heavy with spawn, she approached the weed and appeared to examine it, passing around it several times. Then I saw that her ventral surface was pressed against the weed and that its branches were being caught together by a viscid pure white cord having the diameter of a thick thread. It

clung tenaciously to every branch it touched. Along the cord were large numbers of small eggs. When 4 or 5 inches of the cord had been attached, the fish would rest, the male taking her place and hovering over the eggs, which he guarded with a viciousness altogether unexpected in so small a fish. He withdrew when his mate resumed egg laying. She frequently pushed her way through the clump of weed, but more often passed around it, the silken tenacious cord binding it together in a globular or oval mass about the size of a hen's egg. The entire nest * * * was formed in about two hours, the fish dropping to the bottom of the tank after each effort and lying there for ten or twenty minutes.

I had taken a series of photographs of the nest, and by removing the eggs to a glass globe, in turn placing them in the interior of the large tank so that they would not be disturbed, I soon had the young for examination.

This seems to me the simplest method of observation, namely, open, free, well-lighted tanks, with large skylight, so that the natural conditions of the ocean are more or less obtained; aeration from above, so arranged that it can be increased in the case of surf fishes, or decreased for deep-water forms; special tank for photographing fish at various stages of development, etc., at once simple and productive of results of value to students or laymen.

EFFECTS OF CHANGES IN THE DENSITY OF WATER UPON THE BLOOD OF FISHES

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The fact of variation in the number of human blood corpuscles in health has been known for some time. Stierlin (1889) found variations in individual men of 1,650,000 per cubic millimeter and somewhat larger variations in women. Viault (1890) noted a marked increase in cases of residents at high altitudes. Some physiologists suggest that the increased number is probably not due to increased formation of red corpuscles but for one thing to evaporation of water from the surface and loss of water from the blood. Yet others have found in animals kept at low pressures that there occurs an increase in the number of corpuscles. Hill (1906), reviewing this work, notes an increase in hemoglobin and adds that it is a reaction on the part of the organism to compensate for low oxygen pressure at high altitudes. Although the other side of this question, the changes in the organism due to increased atmospheric pressure (caisson disease), has been investigated, the principal effect noted has been the presence of air bubbles in the blood and other tissues, the fatal effect of which is well known. The effect on the corpuscle count has not been noted.

Dr. F. B. Sumner, director of the biological laboratories of the Bureau of Fisheries at Woods Hole, Mass., who is interested in the cause of the death of salt-water fishes in fresh water and whose investigations will be referred to, suggested to the writer that he study the effect on the blood of fishes subjected to changes of density in the water. Part of my time has been devoted to this problem during the last three summers, with facilities and material afforded by the Bureau of Fisheries.

Sumner (1905) found that well-marked changes in weight resulted in certain cases where the density of the water in which fishes were kept was increased or decreased. He showed that although at first thought these changes might have been expected on the assumption that we were dealing with an osmotic action through semipermeable membranes, yet in other cases the changes did not follow

these laws and the phenomena appeared to be complicated by physiological and chemical factors of an obscure nature. In one case (the carp) it was shown that the changes took place through the gills. In another paper (1907) the same author confirmed the last named result by experiments with the tautog. He also found seasonal differences in the osmotic phenomena and says that "these differences may perhaps be due to differences of temperature but are more probably due to seasonal variations in the physiological condition of the animals."

While not entering into the work in detail, such a course necessitating constant reference to figures, I will give the results of a few experiments and discuss the same.

I wish to corroborate the work of Sumner as to gain in weight of *Fundulus heteroclitus* when placed in fresh water. In this case the fishes were kept in separate dishes and the record of each individual fish was kept. They were taken out and weighed at intervals. The percentage of gain was obtained in each case and for each period. It was found that there was considerable variation. Thus in one experiment there is noted a gain of 13 per cent in one individual, while in the case of another fish of the same lot there was a gain of 2.1 per cent. The average gain was 5 per cent, or if we disregard the case of 13 per cent gain, the average was 4 per cent.

But it may be questioned what right we have to throw out the case of 13 per cent gain. In the first place, this is from two to six times as great as the gain in each of the other cases. What is more important, however, is that it is not a normal case—that is, the fish was not in normal condition, for on referring to the record it is found that at the end of six hours it had turned on its side and a few hours later was dead. This was true of other similar cases. Wherever there was an extraordinarily large initial gain it was noted that early death took place. Again, when in the course of the experiment a marked gain in weight occurred, it was found that this was soon followed by death. It thus appears that there is another factor here than merely osmotic phenomena—that there is a physiological (vital) reaction against osmotic pressures, and as death approaches, this physiological reaction ceases and the phenomena following for a short time at least are osmotic.

Now what is the effect on the blood when this species of fish is placed in fresh water? A familiar experiment in histology is to observe the effect on the corpuscles of distilled or tap water and of concentrated salt solutions. There are distinct effects which end in the destruction of the corpuscles. But do similar changes take place when the living organism (i. e., a salt-water fish) is placed in fresh water? An experiment was devised whereby one lot of *Fundulus heteroclitus* was kept in normal sea water and a second lot in fresh water. After certain periods of immersion (two hours, etc.) blood smears from fishes in each of the

two lots were made on the same slide at the same time and stained simultaneously with Wright's blood stain, were then dried, and mounted in balsam at the same time. A careful examination with the twelfth oil immersion showed no measurable differences in the corpuscles themselves. This was true in other similar tests. In other words, whatever changes these different solutions have on blood it may be said that these changes do not reach the corpuscles themselves.

A series of experiments was made to ascertain whether there was any change in the corpuscle count due to changes in water density. In the case of mountain sickness it has been shown that at high altitudes there is a physiological reaction on the part of the organism to the effect that per cubic millimeter there are more corpuscles manufactured to take up more oxygen, and thus supply the organism with its normal amount. If fishes are placed in fresh water, is the blood diluted? This would be shown by a decrease in the number of corpuscles. To test this, hemocytometer tests were made upon the blood of normal *Fundulus heteroclitus*. The average blood count of eight was found to be 2,749,000. Four fish placed in distilled water for 1¼ to 2¼ hours were examined in the same way and the average blood count was found to be 2,171,000. In two experiments with distilled water there was at first a decrease in the number of corpuscles counted, then a gradual increase, which increase later passed up to and above normal. The last-named experiment indicates that there is at first a reduction, due to influx of water. After the reduction in number of corpuscles there is an increase, which indicates a reaction on the part of the organism to get back to the normal condition. Experiments in which *Fundulus heteroclitus* was subjected to fresh water show, in the main, that the gain in weight which is at first noticeable disappears after a few days and the weight of the organism falls below normal and the decrease continues. This is undoubtedly due to starvation. It may be objected that these fishes can not live very many days in fresh water. In distilled water, no, but in ordinary tap water, yes. On July 10, 1908, I placed ten *Fundulus heteroclitus* in a large rectangular dish containing about 20 liters of fresh tap water. In the bottom was placed some gravel from the shore near by, the gravel having been thoroughly washed. Most of the fishes died during the next three or four weeks, but one fish was alive and apparently in good condition on September 8, 1908, after sixty days. It should be said that the tank in which this specimen was kept was washed out thoroughly once a week and the fish fed. A rough test of the water with silver nitrate and nitric acid was made toward the end of the period, and a slightly greater amount of chlorides was indicated than was present in the fresh tap water. This agrees with Sumner's statement that a slight addition of salt water to fresh water was sufficient to keep the fishes alive, and therefore the death of fishes in dilute solutions was probably not due to lowering of osmotic pressures. To show the

extreme diluteness of salt in the above case, I may add that it took the same reading with the specific gravity hydrometer as did tap water.

In another series of experiments the percentage of hemoglobin was determined with Dare's hemoglobinometer. Although this was less satisfactory, yet the average percentage of hemoglobin of 18 normal *Fundulus heteroclitus* was found to be considerably more than the average in the case of 29 specimens of the same species kept in fresh water for a certain length of time. Have we, however, a right to say that the corpuscles are thus deficient in hemoglobin? Since we have good reason for believing that there is an influx of water and that this takes place through the gills, the reduction in number of corpuscles and a lowering of percentage of hemoglobin shows that the blood has been diluted. We can also obtain the specific gravity of the blood. This was done, by the Hammerschlag method, in which a drop of blood is placed in a solution of benzole and chloroform and enough of each added so that the drop is suspended. The specific gravity of the mixture then would be the same as that of the blood and could be learned by the small hydrometer used for such work. The specific gravity of blood of 20 *Fundulus heteroclitus* was found to be 1.0510. In an experiment in which 22 *Fundulus heteroclitus* were kept in fresh water from two to eight hours the average specific gravity of the blood was 1.047+. In an experiment in which dogfish (*Mustelis canis*) were used, the average specific gravity of the blood of three was 1.0466. After about two hours immersion in fresh water the average specific gravity was 1.0417. Four determinations were made with each fish in the first part of this experiment and similarly in the second part. There was practically no loss of blood except that used in the determination, which fact is mentioned to anticipate the objection that the reduced specific gravity is due to loss of blood, as in the case of hemorrhage in man, when the specific gravity of the blood drops.

It is an established fact that the more dilute a solution is as compared with distilled water the nearer is its freezing point to that of distilled water. By the aid of a Beckman thermometer I obtained the freezing point of distilled water and by the same means the freezing point of the blood serum of a number of dogfish. The average lowering of the freezing point of blood serum of 7 dogfish taken from sea water was found to be 1.934°. Now if there is a slighter depression in the freezing point of blood serum of dogfish kept in fresh water for a certain period, then that means that the blood of such dogfish has been diluted, for such blood is nearer the condition of distilled water than the normal serum. The depression of the freezing point of the serum of 11 dogfish kept in fresh water for one hour was obtained. The average for five experiments was found to be 1.548°. We have already seen that the depression of the freezing point in case of normal dogfish serum was 1.934°. Hence we find that there was dilution of the blood.

In conclusion it may be said that when fishes are kept in fresh water there is a decrease in the number of corpuscles per cubic millimeter, a lowering of the hemoglobin percentage, a lowering of the specific gravity, and a lessening of the depression of the freezing point, all of which shows a dilution of the blood. But, on the other hand, is there shown a concentration of the blood when fishes are placed in a more dense medium? In the case of 19 *Fundulus heteroclitus* kept in sea water, the density of which was increased to about 1.040 by the addition of 25 grams of sea salt to each 1,000 of sea water, the average percentage of hemoglobin was found to be 77 per cent, as compared with 51 + per cent in the case of 18 normal fishes.

As to the number of corpuscles per cubic millimeter, the following experiment was devised: The average number of corpuscles in 8 individuals has been found to be 2,749,000 per cubic millimeter. A fish placed for an hour in a solution of sea water and sea salt so that the specific gravity was 1.050 showed a corpuscle count of 3,072,000 per cubic millimeter. After 2½ hours immersion in sea water and sea salt whose specific gravity was 1.068 the corpuscle count of another specimen was 3,912,000 per cubic millimeter. The average blood count of 14 *Fundulus heteroclitus* kept in a solution of sea water to every liter of which was added 25 grams of sea salt was found to be 3,539,000, while in another case the blood count of two fishes in a solution of sea water to every liter of which was added 45 grams of sea salt was found to be 4,217,000 per cubic millimeter.

At the same time in another experiment record was kept of the weight of the fishes and it was found that they lost steadily in weight while the corpuscle count increased. The same general results were obtained in all the experiments of this nature. From a great many experiments I can corroborate the statement of Sumner as to loss in weight when placed in more dense solutions. As to the change in specific gravity, fishes taken at the same time as those used in getting the normal specific gravity were experimented upon. On placing a lot of 10 in a solution of sea water and sea salt to raise the specific gravity to 1.045 for a period of nearly three hours, the specific gravity of the blood was found to be 1.054. During that time the fishes had lost 7.5 per cent in weight. On remaining in same solution nearly six hours, the average specific gravity was 1.060 and the fishes had lost 11 per cent in weight.

In another experiment with a solution of 1.040 specific gravity there was noted a gradual increase in specific gravity of the blood during the first day. This increase persisted in the case of those examined during the next day, while in 8 specimens examined two days later there was a decrease toward normal in the specific gravity noted. Although this one experiment is inconclusive, it indicates a reaction toward the normal. There is such a thing as normal specific gravity of the blood, and any marked departure is pathological. Hence the

lowering of the specific gravity noted above might be interpreted as a reaction of the organism toward the normal condition. The water necessary to dilute the blood could be drawn in from the tissues.

An experiment was devised to test the relation between temperature and the lowering of the specific gravity of the blood. Three lots of fish were used.

Lot A.—Sea water at temperature of laboratory, 18° C.

Lot B.—Fresh water at 27° C.

Lot C.—Fresh water at 7° C.

The fishes were kept in these solutions from one to six hours. At the end of that period the average specific gravity of blood of—

Lot A was 1.0506, 18° sea water.

Lot B was 1.0463, 28° fresh water.

Lot C was 1.0501, 7° fresh water.

In other words, the cold water had prevented the decrease in specific gravity.

Now it is known that temperature is an important factor in osmotic exchanges and also in physiology of circulation. Therefore, whether the more sluggish movement of the blood through the gills is responsible for the difference between B and C or whether the lowering of temperature produced a condition in the gill membrane making osmotic changes more difficult can not be determined at present. We have seen from the previous experiments that if fishes are placed in a more dilute solution the blood is diluted; if placed in a more concentrated solution the blood is concentrated. It is not believed, however, that in the time during which the fishes were subjected to these various media there was any increased formation of red corpuscles or any destruction of the same.

Are the phenomena described above purely osmotic, and thus physical in their nature, or is there something more—that is, physiological or vital—concerned here? Certainly some of the phenomena observed above lead toward the latter interpretation. The great adaptability of the organism is well shown in the case of the specimen living in fresh water for two months, and again in the case of a few fish which lived for over a month in a solution the concentration of which was increased 50 per cent. It must be remembered that *Fundulus heteroclitus* is found not only in sea water but also in brackish water and inlets of fresh-water streams. Whether the above changes are true of the teleosts which are strictly marine, I can not say.

INTERNAL PARASITES OF THE SEBAGO SALMON

By Henry B. Ward, Ph. D.
Professor of Zoology, University of Illinois

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

CONTENTS.

	Page.
Historical survey	1153
Parasites of Atlantic salmon, with tabulated summary	1153
Parasites of Pacific salmon	1172
Observations on the Sebago salmon	1173
Specific relationships	1173
Source of parasites	1174
A new trematode parasite	1176
Cestodes	1184
Proteocephalus pusillus, nov. sp	1186
Sparganum sebago, nov. sp	1187
Nematodes	1188
Résumé and conclusions	1189
Bibliography	1192
Explanation of plate	1194

INTERNAL PARASITES OF THE SEBAGO SALMON.

By HENRY B. WARD, Ph. D.,
Professor of Zoology, University of Illinois.

In connection with other investigations of the United States Bureau of Fisheries in Alaska in 1906, I had the privilege of spending two months in study of the parasites of the Pacific salmon. The following year, for comparison of the interesting results of this work with similar studies of Atlantic salmon, I was designated to join a party engaged in a biological survey of Lake Sebago, Maine. During six weeks in this region I examined for parasites a number of the Sebago salmon and secured a series of parasites from other fish in the lake and adjacent waters.

The large amount of valuable material obtained on these two trips has engaged my entire attention during the interval since it was secured, and even yet some questions have not been satisfactorily answered. It forms a most interesting contribution to the parasitic fauna of these important fishes and at the same time throws some light on the general relations between an animal and its parasites, which I hope may be of interest to the scientist and of value to the practical fish culturist. This report falls naturally into three parts—first, a historical summary, which concerns chiefly the European or Atlantic salmon, since this species is the only one that has been studied previous to the present date; second, a report on the findings in the case of the Sebago salmon, which is very closely related to the European species, together with a discussion of the conclusions which may be drawn from these data; and third, a similar report on the Pacific salmon, which is less closely related and rather widely removed geographically from the other two forms. In the present paper are included only the first and second sections of the entire report.

HISTORICAL SURVEY.

PARASITES OF ATLANTIC SALMON.

Rudolphi says that in 1726 Frisch observed a salmon parasite, later known as *Bothriocephalus solidus*, and in 1735 published some record of its occurrence in a paper entitled " De tæniis in pisiculo aculeato, qui in Marchia Brandenburgia vocatur 'Stecherling.' " This is the first account of a salmon parasite to which I have found any reference, and I have been unable to ascertain more precisely the data in this case or to verify the reference.

The oldest record of a salmon parasite that I have been able to verify is found in a paper by Spöring (1753), in which he defends the thesis that inhabitants of fluviatile regions are more annoyed by tapeworms than those of other places, no doubt because of the use of half-raw fish. Of weight for his argument is the list of half a dozen fish, including *Salmo salar*, in which, according to his observations, tapeworm[a] larvæ are present. The view that man was indebted to the salmon for infection with fish tapeworms was generally current in early times and, though supported by no scientific evidence, persisted until finally thoroughly disproved by Zschokke (1890). Now it may be regarded as fully established that man does not acquire a single parasite in any way by the use of salmon as food.

O. F. Müller (1776, 1777, 1780) was the first to describe and name according to scientific principles some of the parasites from *Salmo salar*. He named *Fasciola varica*, afterwards called *Distoma varicum* by Zeder; *Echinorhynchus salmonis*, changed to *E. inflatus* by Rudolphi; *E. lævis*, later changed to *E. nodulosus; Tænia solida*, which later became *Bothriocephalus solidus* Rudolphi, and *Tænia salmonis*, later called *B. proboscideus* Rudolphi.

Goeze (1782) gave the first description of *Echinorhynchus quadrirostris*, later more correctly diagnosed and named *Tetrarhynchus appendiculatus* by Rudolphi (1809). Goeze also gave a good description of the encapsulated nematode larva common in salmon, which he referred to *Cucullanus*, though doubtfully. Rudolphi afterwards named this form *Ascaris capsularia*.

The first formal list of parasites from *Salmo salar* is that given by Rudolphi in 1810, who lists as parasites already recorded for this host eight [b] species, as follows:

Bothriocephalus proboscideus.
Bothriocephalus solidus.
Tetrarhynchus appendiculatus.
Distoma varicum.
Ascaris capsularia.
Dub. (?Cucullanus).
Echinorhynchus inflatus.
Echinorhynchus (?) nodulosus.

It is of interest to note that Rudolphi records opposite every one of these named from six to eight earlier references to the particular species. Five of them were originally observed by O. F. Müller, two by Goeze, and one is a doubtful species.

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[a] Braun (1894), who cites the case, says *Ligula* larvæ, but as this genus has not been recorded for *Salmo salar* I take it to apply only to certain of the host species listed. The original author of course did not distinguish even genera in his observations.

[b] In the appendix (vol. II, part 2, p. 376) Rudolphi lists another find under the name of *Distoma crenatum*. This material was examined by Lühe (1901, 401) and pronounced not a hemiurid, but further determination could not be made.

In a later paper (1819) Rudolphi added to the list no new parasite, *Distoma appendiculatum* Rudolphi being merely another name for *D. crenatum* of the appendix in the earlier work. In this list *Echinorhynchus fusiformis* Zeder is only a change of name from *E. inflatus* of the earlier list; *E. nodulosus* is omitted; *Bothriocephalus solidus* is interpreted as introduced by accident when its proper hosts chance to be eaten by the salmon. Thus the true list of salmon parasites is actually reduced, and numbers only seven in this later list of Rudolphi.

In 1851, Diesing in his "Systema Helminthum" recorded for *Salmo salar* ten parasites, as follows:

Distomum varicum.
Stenobothrium appendiculatum.
Schistocephalus dimorphus.
Dibothrium proboscideum.
Echinorhynchus pachysomus.
Echinorhynchus proteus.
Agamonema capsularia.
Ascaris capsularia.
Ascaris clavata.
Cucullanus elegans.

Although one notes at once the unfamiliar appearance of the list due to numerous changes in the names employed, yet only the last two are actually new forms. Thus, in spite of the frequent attention given to the salmon, the list of its parasites had only increased from five to ten species in the seventy-five years since O. F. Müller first made scientific records of its parasitic fauna in Denmark.

In 1878 von Linstow in the "Compendium der Helminthologie" listed 16 parasites for *Salmo salar*. New are:

Distomum ocreatum Rudolphi.
Distomum reflexum Creplin.
Bothriocephalus cordiceps Leidy.[a]
Tetrarhynchus grossus Rudolphi.
Tetrarhynchus solidus Drummond.

In his "Nachtrag" (1889) the same author includes five new species of parasites recorded for *Salmo salar* since the appearance of the earlier record, namely:

Agamonema communis Diesing.
Distomum miescheri Zschokke.
Bothriocephalus sp.? Zschokke.
Leuckartia sp.? Moniez.[b]
Tetrabothrium minimum von Linstow.

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[a] As indicated in the discussion (p. 1166), this is an error in citation.

[b] Moniez (1881) found three cestodes in the pyloric cœca of a salmon obtained in the fish market at Lille (France), on which he based a new genus, *Leuckartia*. Except for the lack of a scolex, the specimens agree well with *Bothriocephalus infundibuliformis*, better *Abothrium crassum*, to which they may well belong.

Without tracing in detail the further progress of the record, it may be said that at the present date the list includes 47 species, which are enumerated later in this paper. It is of importance for a consideration of the distribution of the salmon parasites, the especial object of this paper, to review the later studies in this field in their geographic arrangement in order to compare clearly the parasites found in one area with those which are present in another. The salmon which have been most intensively studied are those of the Rhine.

Our knowledge of these forms is due largely to a series of papers by the distinguished Swiss helminthologist, Fr. Zschokke, of Basel, which cover the work of many years. The first record of Zschokke (1889) included examinations of 45 fish, of which 42 were found infected with parasites. All the fish were caught in the Rhine in November, December, and January, and the following parasitic species were listed:

Parasite.	Organ infected.	Ratio of infection.
		Per cent.
Distomum varicum Zeder	Œsophagus	11
Distomum reflexum Creplin	do	2
Distomum miescheri Zschokke	do	2
Bothriocephalus infundibuliformis Rudolphi	Pyloric cœca	20
Bothriocephalus sp. (larva)	Encysted	2
Tetrarhynchus solidus Drummond	do	2
Tetrarhynchus grossus Rudolphi	do	2
Rhynchobothrium paleaceum Rudolphi (larva)	do	29
Agamonema capsularia Diesing	do	77
Ascaris clavata Rudolphi	do	4
Echinorhynchus sp	do	4

Not a single parasite lay in the alimentary canal below the pyloric cœca. Monticelli notes that most sharks lose their parasites after a long stay in an aquarium, and Zschokke has observed that marine fish otherwise heavily infested lose their intestinal parasites very rapidly when subjected to fasting in captivity. The Rhine salmon behaves with regard to parasites just like a fasting sea fish. Its parasitic fauna manifests an almost purely marine aspect. Fresh-water elements are scanty and insignificant. Clearly, then, the Rhine salmon takes little or no food during its fresh-water migration. Data on individual species close the paper.

The parasitic fauna of the Atlantic salmon was discussed in extended fashion later by Zschokke (1891) on the basis of his own previous studies and those of earlier authors. In all he had examined the viscera of 129 fish caught in the Rhine. The alimentary canal contained in all cases the thick yellowish or yellow-brown mucus, but never any recognizable remnants of food materials, although once plant fibers and undigested remains of a *Gammarus pulex* were found. As in similar previously reported cases, so here also the occurrence of these fragments should be regarded as purely accidental.

Only four of the 129 salmon examined were free from parasites, and in all 20 species of the latter were recorded from the infested fish. The list of parasites recorded is as follows:

- Ascaris adunca Rudolphi.
- Ascaris angulata Rudolphi.
- Ascaris clavata Rudolphi.
- Ascaris (Agamonema) capsularia Diesing.
- Ascaris (Agamonema) communis Diesing.
- Echinorhynchus acus Rudolphi.
- Echinorhynchus agilis Rudolphi.
- Echinorhynchus proteus Westrumb.
- Distomum varicum Zeder.
- Distomum reflexum Creplin.
- Distomum miescheri Zschokke.
- Schistocephalus dimorphus Creplin.
- Bothriocephalus infundibuliformis Rudolphi.
- Bothriocephalus osmeri (larva) von Linstow.
- Bothriocephalus sp. I (larva).[a]
- Bothriocephalus sp. II (larva).
- Rhynchobothrium paleaceum (larva) Rudolphi.
- Tetrarhynchus solidus Drummond.
- Tetrarhynchus grossus Rudolphi.
- Tetrarhynchus macrobothrius von Siebold (= Stenobothrium appendiculatum Diesing).

Five of these species (*Ascaris capsularia, Distomum varicum, Bothriocephalus infundibuliformis, Rhynchobothrium paleaceum,* and *Tetrarhynchus macrobothrius*) are abundant, almost regular in their occurrence, while the other forms are relatively rare in the Rhine salmon. The common parasites were also usually abundant in the individual host; thus 20 to 40 specimens of *Ascaris capsularia* were often found in a single host. Of *Distomum varicum,* from 30 to 50 individuals were taken from the œsophagus of one fish. In some cases *Bothriocephalus infundibuliformis* was present in large numbers, but usually in one or a few weak, starved specimens. *Rhynchobothrium paleaceum* and *Tetrarhynchus macrobothrius* occurred in from 20 to 25 individuals in a single host. All other parasites were found in small numbers, often only a single specimen of any one species.

Among the 129 Rhine salmon investigated 4 were free from parasites, 55 sheltered a single species of parasite, and 43 but two species, while 20 had three species, 6 had four species, and 1 had five species of parasites.

[a] The various bothriocephalid larvæ which occur in the salmon are discussed in a separate paper by Zschokke (1890). On the basis of morphologic data he inclined in this paper to the view that five different forms, indicating as many species, might be distinguished. Later studies showed the first to belong to *Bothriocephalus osmeri* von Linstow. This is the form he listed at first (1889) as *Bothriocephalus* sp. The second is sp. I of the table, the third and fourth are united as sp. II of the table, and the fifth becomes sp. III of the table (see p. 1168).

In not a single case was a parasite found in the alimentary canal below the pyloric cœca. Indeed, parasites which in other hosts inhabit only the intestine, were found in the Rhine salmon to infest stomach and œsophagus, as if better protected there than in the vicinity of the anus. The Rhine salmon loses its intestinal guests like any fasting fish, and through the exclusion of food any new importation of worms is prevented. From the absence of parasites behind the pyloric cœca one may conclude indirectly that *Salmo salar* really fasts in the Rhine. When this species enters the river it is richly laden with parasites. It loses its intestinal guests and these are not replaced by any new supply. There remain only the natural inhabitants of the anterior regions of the canal and those which can withdraw thither. Even these protected species diminish in number of species and individuals as the salmon remains longer in fresh water and climbs higher in the stream, until finally there are left only encapsulated forms. The journey up the Rhine has proved at the same time a means of eliminating the intestinal parasites. Some investigators, although without knowledge of these facts, have yet endeavored to explain the migration of many fish as due to the necessity of freeing themselves from parasites acquired in the ocean.

Salmon caught in Holland, in the lower reaches of the Rhine, are richly infested with parasites. Several species were regularly found in large numbers and the parasitic fauna recalls strikingly that of the ocean salmon. *Distomum varicum* was very abundant in the œsophagus and *Bothriocephalus infundibuliformis* in the pyloric cœca. But fish from the upper reaches of the Rhine presented a radically different picture. The parasites in œsophagus and stomach were very rare. *Distomum varicum* had disappeared and *Bothriocephalus infundibuliformis* appeared only as single, weak, emaciated specimens. Often the entire alimentary tract yielded no trace of a parasite.

The parasitic fauna of the Rhine salmon decreases in proportion as the fish ascends the stream.

A study of the seasonal distribution of parasites in the Rhine salmon evidences that the number of species present becomes reduced in the winter months, and the number of individuals also falls off markedly. The minimum is reached in November and December, the months of spawning, when the fish has penetrated farthest upstream. It has lost its unbidden guests on the long journey. The maximum of parasitic infection is found in the summer months, May to July, when the schools of salmon enter the river. Naturally the journey exerts no influence upon those parasites which inhabit closed organs.

The question next considered is the origin of the salmon's parasites, whether marine, limnetic, or indifferent in character. The analysis of the forms recorded indicates that the Rhine salmon does not exhibit a single true limnetic parasite,

and its most abundant guests are typically marine. In spite of a long and repeated sojourn in the river it does not infect itself with a single fresh-water parasite, a fact that indicates strongly the complete fasting of the salmon while in the Rhine. In other migratory fish the marine elements become greatly reduced or even disappear entirely. Yet tabular comparisons show that in contrast with the Rhine salmon all other migratory fish infect themselves in fresh water more or less strongly with parasites, thus indicating that whereas the salmon fasts in the Rhine, its near relatives feed abundantly on wandering from the ocean into the river.

It was possible to examine also 34 salmon from the Baltic Sea; all of them were infected, and a total of 12 species of parasites were recorded from them, as follows:

Ascaris adunca Rudolphi.
Ascaris (Agamonema) capsularis Diesing.
Ascaris (Agamonema) communis Diesing.
Ascaris aculeati von Linstow.
Echinorhynchus acus Rudolphi.
Echinorhynchus pachysomus Creplin.
Distomum varicum Zeder.
Distomum appendiculatum Rudolphi.
Bothriocephalus infundibuliformis Rudolphi.
Bothriocephalus sp. II (larva).
Bothriocephalus sp. III (larva).
Triænophorus nodulosus Rudolphi (larva).

The Baltic salmon is much more heavily parasitized than the salmon of the Rhine. Seven parasites are common to both, and of these five are more abundant in the Baltic salmon and two only more abundant in the Rhine salmon, while six parasites of the former do not occur in the latter. The relative infestation of the two forms is shown in the accompanying synopsis:

Fish.	Number examined.	Not infected.	Infested with parasites of given number of species.				
			1.	2.	3.	4.	5.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Rhine salmon	129	3.1	42.6	32.5	16.5	4.6	0.77
Baltic salmon	34	0	50	23.5	17.6	8.8	0

Of parasitic species found in the Baltic salmon, *Bothriocephalus infundibuliformis* was present often in enormous numbers, and the same was true of *Distomum varicum*. On the other hand *Ascaris capsularis* did not manifest the frequence or the abundance already noted for the Rhine salmon. Everything indicates a rich and uninterrupted consumption of food by the Baltic

type in contrast with the fasting Rhine fish.[a] Parasites are also found in the intestine behind the pylorus, where the Rhine salmon remains free from parasites. Among the intestinal parasites of the Baltic salmon also are included no true limnetic species. Such only lie encapsulated in various organs. This indicates that the infection with the true fresh-water parasites, *Cucullanus*, *Triœnophorus*, *Ascaris aculeati*, actually occurs in the rivers. The Baltic salmon comes into fresh water as richly laden with parasites as the fish caught in the lower stretches of the Rhine in Holland. While the parasitic fauna of the Rhine salmon decreases in proportion as it ascends the stream, that of the salmon in many other rivers is enriched by numerous limnetic elements. The natural explanation lies in the fasting of the Rhine salmon, whereas its relatives in other streams do not cease taking food. The Baltic salmon, having returned to the ocean, loses the limnetic parasites of the open intestine but retains those located in the closed organs of the host.

The material is too scanty to determine a seasonal distribution, if any exists, and in fact the food of the Baltic salmon undergoes little change throughout the entire year, so that no general modification would be expected in the parasitic fauna, variations being merely of an individual or casual type.

Upon a careful study of the individual species the parasitic fauna of the Baltic salmon manifests a more varied aspect than that of its relative. There are 2 pure marine forms, in contrast to 8 in the Rhine salmon, 2 pure limnetic species as against not a single one in the other host, 6 parasites found in both marine and fresh-water fishes, and 3 parasites found only in the Baltic salmon, with a fourth which can not be assigned with certainty to either type of environment. It is very striking that the purely marine *Tetrarhynchi* so abundant in the Rhine salmon have not yet been demonstrated in the Baltic fish. These relations are indicated in the appended table of parasites from the European salmon, collated from various authors.

The Rhine salmon shelters a purely marine parasitic fauna, while the Baltic salmon reckons many limnetic forms among its parasitic guests. This remarkable condition finds its explanation in the continued feeding of the latter type,

[a] One should not forget in estimating this factor as presented by Zschokke that in one important respect conditions are not identical. The Baltic salmon are still in salt water; not until they enter some estuary and begin the ascent of some river do they meet the fresh water environment to which the Rhine salmon investigated by Zschokke are subject. To secure an exact parallel one should compare the Baltic salmon with such of the Rhine variety as may be captured in the North Sea. Zschokke refers in a later paper to some taken from this body of water and notes in their case also that the average degree of infection with parasites is greater than in the case of those fish taken from the Rhine stream itself. This fact only emphasizes the immediateness and definiteness of the effect on the parasitic fauna of the salmon which is produced by the fresh water environment and abstinence from food.

even in fresh water, and the resulting enrichment of its parasitic fauna with limnetic forms when it returns to the sea.

The parasitic record reflects clearly the manner of life led by any host.

In all, 33 species have been recorded from this salmon, making the list of its parasites one of the longest known for any fish. The list of these is then given, as follows:

Ascaris adunca Rudolphi.
Ascaris angulata Rudolphi.
Ascaris clavata Rudolphi.
Ascaris (Agamonema) capsularis Diesing.
Ascaris (Agamonema) communis Diesing.
Ascaris aculeati von Linstow.
Cucullanus elegans Zeder.
Echinorhynchus proteus Westrumb.
Echinorhynchus pachysomus Creplin.
Echinorhynchus acus Rudolphi.
Echinorhynchus agilis Rudolphi.
Distomum varicum Zeder.
Distomum reflexum Creplin.
Distomum miescheri Zschokke.
Distomum appendiculatum Rudolphi.
Distomum ocreatum Rudolphi.
Distomum tereticolle Rudolphi.
Distomum sp. McIntosh.
Bothriocephalus infundibuliformis Rudolphi.
Bothriocephalus cordiceps Leidy.
Bothriocephalus osmeri (larva) von Linstow.
Bothriocephalus sp. I (larva) Zschokke.
Bothriocephalus sp. II (larva) Zschokke.
Bothriocephalus sp. III (larva) Zschokke.
Schistocephalus dimorphus Creplin.
Triænophorus nodulosus (larva) Rudolphi.
Leuckartia sp. Moniez.
Tetrabothrium minimum von Linstow.
Rhynchobothrium paleaceum Rudolphi.
Tetrarhynchus solidus.
Tetrarhynchus grossus Rudolphi.
Tetrarhynchus macrobothrius von Siebold (=Stenobothrium appendiculatum Diesing).
Tetrarhynchus sp. McIntosh.

The paper of Zschokke closes with a detailed discussion of the biology and relationships of the individual salmon parasites, including citations of the work of previous investigators on these forms.

In a later paper Zschokke (1896) lists the parasites of salmon caught in the Rhine at Basel, including the results of examinations extending over several years and embracing 16 species, as follows:

Bothriocephalus infundibuliformis Diesing.
Tetrarhynchus solidus Drummond.
Tetrarhynchus sp.
Schistocephalus dimorphus.
Distomum varicum Zeder.
Distomum appendiculatum Rudolphi.
Distomum ocreatum Rudolphi.
Distomum reflexum Creplin.
Distomum miescheri Zschokke.
Ascaris clavata Rudolphi.
Ascaris capsularia Diesing.
Ascaris sp.
Ascaris sp.
Echinorhynchus clavæceps Zeder.
Echinorhynchus acus Rudolphi.
Pisicola geometra Linnæus.

Unreported previously are *Echinorhynchus clavæceps* Zeder, *Pisicola geometra* Linnæus, and possibly also two undetermined species of *Ascaris*. Eliminating forms which do not properly belong to the Rhine at Basel and adding species recorded previously, the net result is 17 species of parasites in the salmon at Basel, or one-third of the total known parasitic fauna of that region. Of these 17, 13 are characteristic of the salmon and wanting in other fish there. The large majority of the list are of purely marine character and a further group is characteristic of migratory fish, leaving nothing of a limnetic type save *Pisicola geometra*, a leech which is merely a temporary ectoparasite.

This paper records also the results of the examination of additional salmon from the North Sea, the lower Rhine, and the middle and upper Rhine, making the grand total of 179 Rhine salmon examined by this author. The only new parasite recorded is *Scolex polymorphus* Rudolphi. Again, later, Zschokke (1902, p. 128–130) discusses the records of his earlier work without adding any new data.

In studies on the Rhine salmon Hoek (1899) records that he found in the young fish an ascarid, according to Fritsch *A. clavata*, and repeatedly specimens of a species of *Echinorhynchus* which Fritsch names *E. pachysomus* Creplin, though he did not observe it in the young salmon. In Hoek's opinion the forms obtained, though not fully grown, agree better with the description of *E. proteus* Westrumb, and indeed with the more limited concept of the name according to Hammann. Hoek observed not infrequently that young salmon were infested with a leech, *Cystobranchus* (*Pisicola*) *respirans* Troesch, which lived as an ectoparasite on the skin.

Concerning the Baltic salmon, other fragmentary data are also on record. Olsson (1867) reported *Bothriocephalus proboscideus* Rudolphi as frequent in *Salmo salar* both from fresh and from salt water during April and August. Later the same author (Olsson, 1876) listed *Distomum appendiculatum* Rudolphi as frequent in *Salmo salar* during August. Again (1893) he reported *Distoma appendiculatum* Rudolphi from the stomach as abundant in July. The material came from the Baltic Sea and the Gulf of Bothnia.

Hausmann (1897) lists from *Salmo salar Distomum appendiculatum, D. ocreatum, D. reflexum*, and *D. varicum*. Among 20 specimens examined 13 only were infested with trematodes.

Mühling (1898) records from *Salmo salar* in East Prussia six species of parasites, as follows: *Bothriotænia proboscidea, Apoblema appendiculatum, Echinorhynchus acus, Ech. fusiformis, Ech. proteus*, and *Ech. pachysomus*. The first two are very common, the others occasional. *Ech. fusiformis* is cited after Neumann.

G. Schneider (1902) reports the following data concerning salmon parasites in Finland: A salmon 1 m. long, caught November 6, 1900, in the mouth of the river, was infested with several hundred individuals of *Bothriotænia proboscidea* Batsch, which entirely filled the pylorus portion of the intestine and of the pyloric cœca. Otherwise the intestine contained no parasites and no food. A second salmon, investigated fresh July 2, 1902, had in the intestine the young and adult *Bothriotænia proboscidea* Batsch and one *Echinorhynchus* larva, which, however, evidently came from fish that had been eaten. In the stomach of this salmon he found *Clupea sprattus* Linnæus [p. 18 the name is given as *Clupea harengus membras* L.] and in the intestine remains of digested fishes, probably also herring. The synchronus presence of herring remains and of very young *Bothriotænia* in the intestine of this salmon confirms fully his formerly expressed opinion that the salmon infects itself with tapeworms through eating the herring.

According to Schneider (1902, p. 20), Kessler in a Russian paper reported the occurrence of adult *Bothriotænia proboscidea* in the intestine of *Salmo salar* from Lake Onega. This body of water is directly connected with the Baltic Sea, where, according to Mühling, as just noted, this species is a very common parasite of the salmon. Schneider has also found it abundant in salmon from the Gulf of Finland.

No doubt some observations have been made on the parasites of salmon in the Scandinavian peninsula, but they have thus far eluded my search.

Concerning the parasites in the British Isles many observations are on record. But they concern individual investigations at particular locations, and as a rule do not cover any continuous study of the problem. In consequence the lists are not as complete as those already cited for the Rhine and the Baltic,

and it is somewhat difficult to draw a precise comparison with the data for the latter regions. First may be placed such records as concern streams directly connected with the North Sea, and hence with the body of water from which the Rhine salmon come.

Concerning the parasites of salmon in the Tay, McIntosh (1863) has recorded certain data. More than 100 fish were examined, few were entirely free from parasites, many were richly infested. The parasitic species were both frequent and abundant, although only 10 species are definitely recorded, as against 14 in the Baltic and 20 in the Rhine salmon. The species from Tay salmon McIntosh lists as follows:

Ascaris (Agamonema) capsularia Diesing.
Echinorhynchus proteus Westrumb.
Echinorhynchus pachysomus Creplin.
Distomum varicum Creplin.
Distomum tereticolle Rudolphi.
Distomum sp.
Bothriocephalus infundibuliformis Rudolphi.
Tetrabothrium minimum von Linstow.
Tetrarhynchus macrobothrius von Siebold.
Tetrarhynchus sp.

The examination of this list shows clearly that the Scotch salmon combines elements from the parasitic fauna of both its relatives, the Rhine salmon and the Baltic salmon. The strong and continued infestation of the intestine below the pylorus goes to establish the fact that the taking of food is continuous.

No seasonal distribution of parasites could be noted, but the character of the parasitic species was striking. One pure marine species and two almost equally such, together with five characteristic salmonid parasites, show that the major portion of the parasitic fauna is of marine origin. On the other hand, the intestinal parasites were in large part not marine, but limnetic forms or such as are typical in the salmon. As in the Rhine salmon, so also in the Tay, the marine alimentary parasites are gradually lost without being renewed. They are replaced by such as are of evident limnetic character. Hence the conclusion of McIntosh, based on other evidence also, that the Tay salmon does from time to time take nourishment during its stay in fresh water. A comparison of the parasitic fauna of the three salmons gives, according to Zschokke, the following:

Fish.	Number of parasitic species.	Typical for the particular salmon.	Found also in other salmon and other localities.	In other migratory fish as well as the salmon.	Besides in migratory fish also in—		
					Marine fish.	Limnetic fish.	Both marine and limnetic.
Rhine salmon	20	2	2	2	8	1	5
Baltic salmon	14	1	2	1	2	2	6
Tay salmon	10	3	1	0	1	2	3

Much later than the work just outlined is a paper by Tosh (1905) in which he discusses his work on the internal parasites of the Tweed salmon. The material was collected in 1895 at a single place. The author notes the distinctly marine character of the parasitic fauna of this salmon, attributing it to the fact that "salmon do not feed in the fresh water of a short river like the Tweed, except under extraordinary conditions, when a prolonged stay is imposed upon them." In all he lists 15 species, as follows:

Ascaris capsularia Rudolphi.
Ascaris acuta Müller.
Ascaris obtusocaudata Zeder.
Distoma varicum Rudolphi.
Distoma ocreatum Rudolphi.
Distoma miescheri Zschokke.
Echinorhynchus acus Rudolphi.
Echinorhynchus proteus Westrumb.
Echinorhynchus angustatus Rudolphi.
Bothriocephalus infundibuliformis Rudolphi.
Tetrarhynchus grossus Rudolphi.
Tetrarhynchus macrobothrius Rudolphi.
Tetrabothrium minimum (larva).
Tetrabothrium sp. (larva).
Tænia sp. (larva).

Details are given concerning the frequence, appearance, and biology of each form. The most important is held to be *Bothriocephalus infundibuliformis*, which, according to an appended table, occurs in 26.4 per cent of the 892 fish examined. It does not seem, in the opinion of Tosh, to be seriously harmful to the host and is found in the largest and best-fed fish in numbers ranging from 1 to 6 per host. The tremendous infestations noted by Zschokke apparently do not occur in this region in the salmon, although observed in the sea trout.

The only notices from Ireland concerning salmon parasites are brief and also of long standing. Drummond (1838), writing in Belfast, described *Tetrarhynchus grossus* from the abdominal cavity of the salmon, which he found only once, and *Tetrarhynchus solidus*, new species, from the peritoneum and mesentery, which he took from three salmon in July, 1838.

Somewhat later Bellingham (1844) listed among the entozoa indigenous to Ireland the following taken from the salmon, namely:

Ascaris capsularia, on the peritoneum; also in 14 other species of fish, all marine.

Ascaris clavata, from intestine and peritoneum; also in 9 other species of fish, all marine.

Distoma varicum, from the stomach; common in some localities and seasons, rare in others.

Tetrarhynchus grossus, from the abdominal cavity; entered in this list on the authority of Drummond (1838).

Tetrarhynchus solidus, from the abdominal cavity; a single specimen loose in peritoneal cavity.

Bothriocephalus proboscideus, from intestine and pyloric cœca; exceedingly common and most so in largest and fattest salmon.

One should always recall the relative value of such comparisons as those in the preceding pages. The fact that from Irish salmon only 6 species of parasites are recorded, from the Scotch form 10 species, from the Baltic form 14 species, and from the Rhine salmon 20 species, is partly accounted for by the amount of attention directed to the various forms. Thus the first record concerning the Rhine salmon (Zschokke, 1889) listed 11 species of parasites obtained in the course of examining 45 specimens of the Rhine salmon. The second record by the same author (Zschokke, 1891) included 20 species of parasites from 129 hosts, and the third record (Zschokke, 1896) gave 23 species of parasites from a total of 179 hosts. Of these 136 came from the Rhine itself and 43 from the sea. More extended study of any host will increase the list of the parasites which it is known to support.

The same species of fish, *Salmo salar*, occurs in streams on the western or American coast of the Atlantic Ocean. Thus far no one appears to have devoted especial attention to the parasitic fauna of the American fish, but some scattered references to species found in our American salmon are recorded by different authors. No doubt the list can be extended considerably by longer search, but so far as I can ascertain the following brief references include all records of salmon parasites made on this continent and published up to the present time.

According to Zschokke (1891) Leidy reported *Bothriocephalus cordiceps* from the intestine of *Trutta salar* Linnæus. The reference, which is apparently cited from von Linstow (1878), is incorrect both in location and content. Leidy (1871) reported on the authority of Professor Hayden "the brook trout, *Salmo fontinalis*, of the headwaters of the Yellowstone River, to be much infested with a species of tapeworm * * * from the abdominal cavity, but not from the intestinal canal * * *. It belongs to the old genus *Bothriocephalus*, and to that section now named *Dibothrium*." This new species was named *Dibothrium cordiceps*. The species was subsequently studied in detail by Linton. I am unable to find any other reference to this parasite in the writings of Leidy or any record of its occurrence in any other than the original host, which was in reality *Salmo mykiss*, the Rocky Mountain trout; the adult parasite occurs in the intestine of the American white pelican, *Pelecanus erythrorhynchus*. This parasite accordingly seems to have no relation whatever to the salmon and should be eliminated from the list of its parasites.

In the catalogue of parasites from various collections in the United States by Stiles and Hassall (1894) there are listed from *Salmo salar Bothriocephalus*

proboscideus from Berlin in the Stiles collection and *Bothriocephalus* sp. from England in the Hassall collection; no specimens whatever are noted as having been taken from autochthonous fish.

In a list of trematodes from Canadian fishes Stafford (1904) records from *Salmo salar* Linnæus, *Derogenes varicus* O. F. Müller, found in mouth, œsophagus, and stomach; *Hemiurus appendiculatus* Rudolphi, found in œsophagus and stomach; *Lecithaster bothryophorus* Olsson (= *Apoblema mollissimum* Levinsen), and *Sinistroporus simplex* Rudolphi, from the intestine. The fish were apparently purchased in the markets in Montreal and represent conditions during the spring and autumn months of 1903.

I have found no further references to the parasitic fauna of *Salmo salar* on this continent. The list contains two species not previously recorded for this host, and yet it is insignificant in comparison with European records for the same host.

Appended hereto is a tabular list of all parasites hitherto reported from *Salmo salar*, arranged according to the place which the parasites hold in the present accepted system. The taxonomy of these groups is at present in such confusion that I have contented myself with entering the names employed by the author cited and in making a few inevitable corrections. Any attempt to adjust the nomenclature adequately would demand an amount of time beyond my present command and an amount of space out of keeping with the rest of this article. By the citation in the table of the authority, date, locality, and location, the reader is enabled to form at a glance a general opinion regarding the importance of any parasite yet reported from the salmon and to follow up its record with the minimum delay.

LIST OF PARASITES HITHERTO REPORTED FROM SALMO SALAR.

Name of parasite.	Condition.	Reported by—	Date.	Locality.	Location.	Frequency.	Notes.
(A) *Cestoda.*							
Abothrium crassum (Bloch)	Adult	Lühe	1899				Correction in name.
Bothriocephalus cordiceps Leidy	Larva	von Linstow	1878	After Leidy 1871	Intestine		Error in citation. True host is Salmo mykiss.
		Zschokke	1891				
Bothriocephalus infundibuliformis Rud	Adult	do	1889	Rhine	Append. pylor	Abundant	Almost regular. See Abothrium crassum.
		do	1891	Rhine and Baltic Sea.			
		do	1896	do			
		Tosh	1905	Tweed	Intestine	Abundant	From 1 to 6 per host.
Bothriocephalus osmeri von Linstow	Larva	Zschokke	1891	Rhine	Intestinal wall	Rare	
Bothriocephalus proboscideus Rud	Adult	Rudolphi	1810		Pylor. cœca	Exceedingly common.	See Abothrium crassum.
		Bellingham	1844	Ireland		Common	
		McIntosh	1863	Tay	Intestine		
		Olsson	1867	Baltic Sea	Append. pylor	Frequent	In hosts from both fresh and salt water.
		Stiles and Hassall.	1894	(Berlin?)			
Bothriocephalus solidus Rud	Larva	Rudolphi	1810				See Schistocephalus dimorphus.
		do	1819				Introduced by accident when its proper hosts chance to be eaten by the salmon.
Bothriocephalus sp. ? Zsch	Larva	Zschokke	1889	Rhine	Intestine	Rare	Later identified as B. osmeri (larva) q. v.
		von Linstow	1889				
Bothriocephalus sp. S. and H	Adult	Stiles and Hassall.	1894	England			
Bothriocephalus sp. I Zsch	Larva	Zschokke	1891	Rhine	Encysted on intestine.	Rare	
Bothriocephalus sp. II Zsch	do	do	1891	do	do	do	
Bothriocephalus sp. III Zsch	do	do	1891	Baltic Sea	do	do	
Bothriotænia proboscidea Batsch	Adult	Mühling	1898	East Prussia		Very common	See Abothrium crassum.
	Young and adult.	Schneider	1902	River and Gulf of Finland.	Append. pylor. and pylor. cœca.	Several hundred	
Dibothrium proboscideum	Adult	Diesing	1851				Do.
Leuckartia sp.? Moniez	do	Moniez	1881	Lille, France	Intestine		Probably Abothrium crassum.
		von Linstow	1889	After Moniez			
		Zschokke	1891	do			
Rhynchobothrium paleaceum Rud	Larva	do	1889	Rhine	Intestine, liver, peritoneum.	Abundant	
		do	1891	do			
Schistocephalus dimorphus Crepl	Larva	Diesing	1851		Ventric		Chance guest. Taken in when proper host is eaten.
		Zschokke	1891	Rhine		Rare	
		do	1896	do			
Scolex polymorphus Rud	Larva	do	1896	North Sea	Intestine		
Stenobothrium appendiculatum Dies	do	Diesing	1851		Intestine, liver		=Tetrarhynchus macrobothrium von Sieb.
		McIntosh	1863	Tay			Larva of Tetrarhynchobothrium bicolor Dies.
		von Linstow	1878				

		Zschokke	1891	Rhine	Ovary, body cav.	Abundant	Almost regular.
		Tosh	1905	Tweed			
Tænia solida O. F. Müller	Larva	Müller	1777				Bothriocephalus solidus according to Rudolphi.
Tænia sp. Tosh	do	Tosh	1905	Tweed		Once	
Tetrabothrium minimum von Linstow	do	von Linstow	1889				
		Zschokke	1891				
		Tosh	1905	Tweed		Most	
Tetrabothrium sp. Tosh	Larva	do	1905	do		Once	
Tetrarhynchus appendiculatus		Rudolphi	1810				
Tetrarhynchus grossus Rud		Drummond	1838	Ireland	Abdom. cav	Only once	
		Bellingham	1844	do	do		Entered on the authority of Drummond, 1838.
		von Linstow	1878		Rectum, perit.		
		Zschokke	1889	Rhine		Rare	
		do	1891	do			
		Tosh	1905	Tweed			
Tetrarhynchus macrobothrium von Sieb	Larva	Zschokke	1891	Rhine	Encysted on viscera		Larva of Tetrarhynchobothrium bicolor Dies.
Tetrarhynchus solidus Drummond		Drummond	1838	Ireland	Perit. and mesen	From 3 salmon	
		Bellingham	1844	do			
		von Linstow	1878		Rectum, perit., intestine.		
		Zschokke	1889	Rhine		Rare	
		do	1891	do			
		do	1896	do	Pylor. cœca		
		Tosh	1905	Tweed	Abdom. cav	A single specimen loose.	According to Tosh, degenerating stage of T. grossus.
Tetrarhynchus sp. McIntosh		McIntosh	1863	Tay	Cyst on rectum	Once	
		Zschokke	1891				
Triænophorus nodulosus Rud	Larva	do	1891	Baltic Sea	Cyst in liver	Once	
		do	1896				
(B) *Trematoda.*							
Apoblema appendiculatum Lev	Adult	Mühling	1898	East Prussia		Very common	Really Brachyphallus crenatus.
Azygia tereticollis	do	Looss	1899				Correction in name.
Brachyphallus crenatus (Rud.)	do	Odhner	1905	Baltic Sea			
		Looss	1907	Königsberg			
Derogenes varicus (O. F. M.)	Adult	Stafford	1904	Canada	Mouth, œsoph., and stomach.		
Distoma appendiculatum Rud. or Distomum appendiculatum.	do	Rudolphi	1819		Intestine, œsoph	Frequent	During August.
		Olsson	1876	Baltic Sea and Gulf of Bothnia.			
		Zschokke	1891	Baltic Sea			
		Olsson	1893	Baltic Sea and Gulf of Bothnia.	Stomach	Abundant	In July.
		Zschokke	1896	Baltic Sea			
		Hausmann	1897				
Distoma crenatum Rud	Adult	Rudolphi	1810		Ventric. et intest	Abundant	Not determinable, Lühe, 1901.
Distomum miescheri Zsch	do	Zschokke	1889	Rhine	Œsoph	Rare	
		von Linstow	1889				
		Zschokke	1891	Rhine			
		do	1896	do			
		Tosh	1905	Tweed			
Distomum ocreatum Rud	Adult	Olsson	1861	Baltic Sea	Ventric		Hemiurus crenatus (Rud.), according to Lühe, 1901, p. 399.
		von Linstow	1889				
		Zschokke	1891	Rhine			
		do	1896	do			
		Hausmann	1897				
		Tosh	1905	Tweed			

LIST OF PARASITES HITHERTO REPORTED FROM SALMO SALAR—Continued.

Name of parasite.	Condition.	Reported by—	Date.	Locality.	Location.	Frequency.	Notes.
(B) *Trematoda* Continued.							
Distomum reflexum Crepl	Adult	von Linstow	1878		Ventric., œsoph		
		Zschokke	1889	Rhine			
		do	1891	do		Once	
		do	1896	do			
		Hausmann	1897			Rare	
Distomum sp. McIntosh	Young	McIntosh	1863	Tay	Duodenum	Once	
		Zschokke	1891				
Distomum tereticolle Rud	Adult	McIntosh	1863	Tay	Intestine	Once	See Azygia tereticollis.
		Zschokke	1891		do		
Distoma varicum Zed. or Distomum varicum.		Rudolphi	1810				See Derogenes varicus.
		Bellingham	1844	Ireland			
		Diesing	1851		Ventric., œsoph	Abundant	
		McIntosh	1863	Tay			
		Zschokke	1889	Rhine			
		do	1891	do			
		do	1896	do			
		Hausmann	1897				
Fasciola varica (O. F. M.)	Adult	Müller	1777				See Derogenes varicus.
Fasciola salmonis O. F. M		do	1780				Probably Hemiurus crenatus, Lühe, 1901.
Hemiurus appendiculatus (Rud.)	Adult	Stafford	1904	Canada	Œsoph., stomach		Probably incorrect determination.
Hemiurus crenatus (Rud.)	do	Lühe	1901	East Prussia		Very common	See Brachyphallus crenatus.
Hemiurus lühei Odhner	do	Looss	1907	Leipzig, fish market.	Œsophagus	Once	
Lecithaster bothryophorus (Olsson)	do	Stafford	1904	Canada	Intestine		=Apoblema mollissimum Levinsen.
Sinistroporus simplex (Rud.)	do	do	1904	do	do		
(C) *Nematoda.*							
Agamonema capsularia Dies	Larva	Diesing	1851		Periton		
		Zschokke	1889	Rhine		Very common	
		do	1896	do			
Agamonema commune Dies	Larva	von Linstow	1889				
		Zschokke	1896	Rhine		Rare	
Ascaris (Agamonema) capsularia Dies	Larva	do	1891	do	Intestinal perit		See Agamonema capsularia.
		do	1896	do	Body cav., liver, spleen, kidney, sex. organs.		
Ascaris (Agamonema) communis Dies	Larva	do	1891	do	Liver		See Agamonema commune.
Ascaris aculeati v. Linstow	do	do	1891	do	Œsoph., liver	Rare	
Ascaris acuta O. F. Müller		Tosh	1905	Tweed		Common	
Ascaris adunca Rud		Zschokke	1891	Rhine	Intest., stomach, œsoph.		
Ascaris angulata Rud		do	1891	do	Œsoph	Very rare	
Ascaris capsularia Dies	Larva	Rudolphi	1810				See Agamonema capsularia.
		Bellingham	1844	Ireland			
		Diesing	1851		Intest., abdom., perit.	Abundant	Almost regular.
		McIntosh	1863	Tay			
		Tosh	1905	Tweed			

Ascaris clavata Rud		Bellingham	1844	Ireland			
		Diesing	1851			Rare	
		Zschokke	1889	Rhine			
		do	1891	do	Encysted on peritoneum and intestinal wall.		
		do	1896	do			
		Hoek	1899	do			
Ascaris obtusocaudata Zed		Tosh	1905	Tweed		Once	
Ascaris spec		Zschokke	1896	Rhine		do	
Do		do	1896	do		do	
Cucullanus elegans Zed		Diesing	1851		Intestine, pylor		
		Zschokke	1891				
Cucullanus (dub.)	Larva	Goeze	1762				Ascaris capsularia acc. to Rudolphi.
		Rudolphi	1810				
(D) *Acanthocephala.*							
Echinorhynchus acus Rud		Zschokke	1891	Rhine	Œsoph., stomach, intestine.	Once	
		do	1896	do			
		Mühling	1898			Occasional	
		Tosh	1905	Tweed			
Echinorhynchus agilis Rud		Zschokke	1891	Rhine	Œsoph	Rare	
Echinorhynchus angustatus Rud		Tosh	1905	Tweed		Once	
Echinorhynchus clavaeceps		Zschokke	1896	Rhine	Intestine	do	
Echinorhynchus fusiformis		Rudolphi	1819				E. inflatus renamed—Rudolphi.
		Mühling	1898			Occasional	Cited after Neumann.
Echinorhynchus inflatus Rud		Rudolphi	1810				
		McIntosh	1863	Tay	Intestine		
Echinorhynchus lævis O. F. Müller		Müller	1777				E. nodulosus according to Rudolphi.
Echinorhynchus ? nodulosus		Rudolphi	1810				
Echinorhynchus pachysomus Crepl		Diesing	1851		Ventric., intestine		
		Zschokke	1891	Baltic Sea			
		Mühling	1898			Occasional	
Echinorhynchus proteus Westrumb		Diesing	1851		Intestine, perit.		
		McIntosh	1863	Tay			
		Zschokke	1891	Rhine	Encysted on perit.		
		Mühling	1898			Occasional	
		Hoek	1899	Rhine			
		Tosh	1905	Tweed		Common	
Echinorhynchus quadrirostris		Goeze	1762				See Cestoda. Tetrarhynchus appendiculatus acc. to Rudolphi.
Echinorhynchus salmonis O. F. Müller		Müller	1777				E. inflatus acc. to Rudolphi.
Echinorhynchus sublobatus Rud		Rudolphi	1810		Ventric		Host species uncertain.
Echinorhynchus sp		Zschokke	1889	Rhine			Afterwards referred to E. proteus.
(E) *Ectoparasites.*							
Lepeophtheirus strömii		McIntosh	1863	Tay	Base of fat fin, caudal rays, eye, and before hyoid.		
Cystobranchus (Pisicola) respirans		Hoek	1899	Rhine	Skin	Frequent	Infesting young salmon.
Pisicola geometra		Zschokke	1896	do	do	Temporary	

PARASITES OF PACIFIC SALMON.

The list of parasites for Atlantic salmon in America, though small, is much more extended than the records concerning the Pacific salmon. While tremendous numbers of the latter fish, which belong to several species of the genus *Oncorhynchus*, are taken every year for commercial purposes, apparently no one has studied the parasitic fauna or done more than to record casually a few data taken during a study of some other factor concerning the species. Even of such notes I have found only a very few.

In a report on the life history of the Alaska salmon, Bean (1890, and also 1893) noted a few items concerning parasites. He mentions the presence in 1889 of numerous intestinal worms in the red salmon and finds that all species of salmon [in fresh water?] are more or less covered with parasitic copepoda.

Much more extensive are the notes made by the brilliant young naturalist and student of the Pacific salmon, Cloudsley Rutter, who only a short time back met such an untimely death.

In the course of investigations on the natural history of the quinnat salmon in the Sacramento River, Rutter (1902) records some interesting items regarding their parasites. A common pest in the adult of this species in fresh water is a parasitic copepod which attaches itself to the gill filaments. Usually not numerous on a single fish, they yet sometimes destroy the gill filaments almost entirely. The intestine of the spawning salmon is frequently inhabited by tapeworms extending into the cœca and at times filling them completely. They do not occur in the stomach. In 1898 they were much more abundant than in 1900. Among 200 young salmon examined from fresh-water stations in the Sacramento basin in May, 1898, and April, 1899, parasites were found in the stomach contents of 31 fish. They were described as of two or three kinds, one elongated [cestode?], the others short and grain-like [trematodes?]. Rutter thinks that residence in fresh water is conducive to the growth of parasites in the stomachs of young salmon. He gives the following tables of their occurrence according to size of host and dates of capture.

OCCURRENCE OF PARASITES IN QUINNAT SALMON FROM SACRAMENTO RIVER.

According to dates of capture.

Month.	Number examined.	Number with parasites.	Percentage with parasites.
January	9	1	11
February	10	0	0
March	10	0	0
April	15	0	0
May	50	4	8
July	21	1	5
August	20	3	15
September	18	3	17
October	30	8	23
November	15	3	20
December	11	8	73
Total	209	31	15

Occurrence of Parasites in Quinnat Salmon from Sacramento River—Continued.

According to size of fish.

Size.	Number examined.	Number with parasites.	Percentage with parasites.
1.4 to 2 inches	61	3	5
2.1 to 3 inches	57	3	5
3.1 to 4 inches	53	10	19
4.1 to 5 inches	30	12	40
5.1 to 6.3 inches	8	3	38
Total	209	31	15

It will be noted that the percentage of infestation increases rapidly with the size and age of the fish, but this would naturally be associated with the more extensive feeding of the older and larger fish, whether in fresh or salt water. In the absence of comparative data for salt water forms to contrast with these of summer residents in fresh water, it is not allowable to attribute this condition to the delayed migration of these fish, as Rutter does. From brackish-water stations 20 young salmon were examined and parasites found in 3 only. This number is too small to be available for comparison with those fresh-water forms noted above. Unfortunately no further data are available concerning the varieties of parasites found either in the adult or in the young specimens. It is probable that the adult parasites are the same as certain forms to be discussed later from the Alaska salmon.

OBSERVATIONS ON THE SEBAGO SALMON.

SPECIFIC RELATIONSHIPS

The Sebago salmon is regarded by some as merely a landlocked variety of the Atlantic salmon, *Salmo salar*, found both in European streams and in the rivers of Maine and northward. By others it is viewed as a separate species, *Salmo sebago*, but in any event closely related to the former. In their extensive catalogue of North American fishes, Jordan and Evermann (1896) include all these forms in the single species *Salmo salar* Linnæus, speaking of its range as follows:

North Atlantic, ascending all suitable rivers in northern Europe and the region north of Cape Cod to Hudson Bay; formerly abundant in the Hudson and occasional in the Delaware, its northern limit in the Churchill, Albany, and Moose rivers, flowing into Hudson Bay; sometimes perfectly landlocked in lakes in Maine and northward, where its habits and coloration (but no tangible specific characters) change somewhat, when it becomes (in America) vars. *sebago* and *ouananiche*. Similar landlocked varieties occur in Europe.

Of the Lake Sebago form which I had the opportunity of studying and which these authors regard as a subspecies, *Salmo salar sebago* (Girard), they write as follows:

Smaller in size, rather more plump in form, and nonmigratory; not otherwise evidently different. Sebago Pond and northward; introduced into lakes in various parts of the country; seldom entering streams; reaches a weight of 25 pounds.

It is important to notice that the same authors also recognize a second subspecies, and this may be the form from which were obtained the parasites reported by Stafford (1904) and already commented upon. Concerning this subspecies, Jordan and Evermann write that *Salmo salar* is—

> * * * represented in Lake St. John, Saguenay River, and neighboring waters of Quebec by the landlocked *Salmo salar ouananiche* McCarthy MS., new subspecies. Still smaller, rarely reaching a weight of 7½ pounds and averaging 3½. An extremely vigorous and active fish, smaller and more active than ordinary salmon, but so far as known not structurally different. Saguenay River, Canada (outlet of Lake St. John), and neighboring waters.

Were it possible to determine definitely whether the records of Stafford concern the oceanic form caught during its migration or the landlocked form, a more definite value could be placed upon his data. In the absence of such information one can not venture to use these records at all in the discussion of the biological problems concerned. What these problems are will be clearer after a more detailed consideration of the case.

SOURCE OF PARASITES.

In view of the close specific connection of the two forms, the European salmon just considered and the Sebago salmon, a comparative study of their parasitic fauna is of unusual interest, especially since the Atlantic salmon spends the greater part of its life in salt water, and after its entrance into fresh-water streams in the course of its migration does not in most cases partake of any food. Consequently whatever parasitic guests it harbors must, as already explained, be of marine origin. The exceptions to this statement are due to accidental infection, and are both small in numbers and insignificant in variety and relative importance. On the other hand, the landlocked Sebago salmon never enters salt water. Its period of active feeding and growth is passed in inland waters, those of Sebago Lake in the case of the specimens we secured and examined. Whatever parasites it harbors are hence obtained in that lake, and are either pure fresh-water organisms or such as have been introduced with the host and subsequently acclimatized to a fresh-water existence. In the case of such parasitic species as undergo direct development, like many nematodes, the introduction of a marine parasite into fresh water involves the habituation of the free living stage, either egg or larva, or both, to the limnetic environment, and this is the identical process involved in the transfer of any free living organism from a marine existence to one in fresh water. In the case of parasites which manifest indirect development with change of host the case is much more complicated. Such parasites usually have one or more brief stages of free existence in the open water as egg, embryo, or larva, like those just referred to. But they also employ one or more intermediate hosts, in which certain parts of the development are passed. Now, either the same marine animals which serve as intermediate hosts in the sea must be found in fresh water also, or must be successfully

introduced at the same time with the primary host and its parasites to which they are related, or, finally, there must be present in the fresh water other animals which can serve successfully as intermediate hosts. The interrelation is thus very complicated and the chance of achieving it so small that in most cases marine forms do not bring the majority of their parasites with them in the transfer to fresh-water existence. In other words, limnetic animals are less heavily parasitized than marine. For this reason the examination of so recent a migrant into fresh water as the Sebago salmon is of great biological interest.

At Lake Sebago only 7 specimens of the Sebago salmon were obtained and examined. These weighed, respectively, 2, 2, 2, 3, 5½, 8, and 16 pounds. While the number examined was from one standpoint small, yet in view of the scarcity of the species in the lake it was fortunately large. The series was also representative of different ages, ranging probably over several years in growth. It seems likely that if marked variations in food materials were found such a range of specimens would indicate the fact through differences in parasitic infestation. Yet there was a striking uniformity in the records in the series. Furthermore, the fish were all examined very soon after capture, and thus any post-mortem wanderings, which certainly do influence the location of parasites collected from market fish, were largely avoided. No doubt there are rare parasites of this species which are not represented in this collection, but, all things being considered, it may be asserted with some confidence that the records give a true picture of the number and location of the parasites infesting them.

The parasites found are recorded in the following table:

RECORD OF PARASITES FROM SALMO SEBAGO.

[x=many. xx=very many. §=more than in fish no. 14—not counted.]

Host.				Parasites, number and location.			
Serial No.	Length.	Weight.	Sex.	Œsophagus and stomach.	Pyloric cœca and adjacent part of intestine.	Intestine behind pyloric cœca.	Body cavity.
	In.	*Lbs.*					
14	16	2	♂	7 Azygia sebago	45 Abothrium crassum.	1 Proteocephalus pusillus.	1 Nematode A.
				(?) 2 Nematode A		1 Azygia sebago	(?) See also stomach.
15	16	2	♂	13 Azygia sebago	§ Abothrium crassum.	1 Proteocephalus larva.	
						1 Bothriocephalid larva.	
						Proteocephalus pusillus.	
16	27	8	♂	xx Azygia sebago [a]	70 Abothrium crassum.	Proteocephalus pusillus.	1 large Bothriocephalid larva.
						1 Bothriocephalid larva.	1 small larval cestode.
32	17	2	♂	1 Azygia sebago	30+Abothrium crassum.		
41	33	16	♂	18 Azygia sebago	80 Abothrium crassum.		33 Nematode B. [b]
							1 Bothriocephalid larva encysted in spleen.
42	19	2¾	♂	xx Azygia sebago	x Abothrium crassum.		3 Nematode A.
106	22	5½	♂	19 Azygia sebago	50 Abothrium crassum.		Not examined.
				(?) 6 Nematode B			(?) See also stomach.

[a] Also in swimming bladder (?). See text.

[b] Viscera a mass of adhesions; parasites difficult to pick out.

A NEW TREMATODE PARASITE.

Every one of the 7 fish examined contained specimens of a new trematode, which I have named *Azygia sebago.* It is relatively insignificant in size and difficult to detect amid the thick white mucus which lines the wall of stomach and œsophagus. Not a single host was without this parasite, and several salmon sheltered considerable numbers; yet in most cases they were not seen in life, but only appeared after the stomach and its contents had been agitated in a preserving fluid. Careful examination of the débris then never failed to disclose some specimens of this worm. Moreover, it was the only species of trematode that was found in the Sebago salmon. The description of the species may properly precede a discussion of its biological characteristics.

The genus *Azygia* was established by Looss (1899, p. 569) to include a well-known European species, *Distomum tereticolle* Rudolphi, which was made the type of the new genus. It was also the only species in the genus; for, as Looss remarks, he had not been successful in finding among the flukes that he knew any form which could be included naturally with the old species, *Distomum tereticolle.* There are at the disposal of the student several good descriptions and delineations of the old species, *Azygia tereticollis* Rudolphi, so that it is possible to determine with precision its structural features; the best of these descriptions is undoubtedly that by Looss (1894).

The new species, *Azygia sebago,*[a] is much smaller than the older form, measuring 10 mm. in maximum length and averaging 5 to 6, or less often 8 mm., in well-developed specimens. Fortunately, I have a large range of sizes, from such as are only barely over 1 mm. in length to the maximum noted, so that it was possible to follow the changes accompanying the assumption of the adult form. Specimens 2.85 mm. long have not yet produced ova.

The general form of the body is cylindrical, bluntly rounded at the anterior end, and tapering slightly toward the posterior end, which, however, is ultimately rounded off. The body is regularly divided into two regions by a shallow furrow at which the direction of the long axis changes more or less (fig. 1), giving the worm in lateral aspect much the appearance of a can-top tightener. While the relation of the regions is very variable, at times forming almost a single straight line and again standing at a considerable angle with each other, yet one can make out these conditions even in specimens which are poorly killed and badly distorted. The anterior region assumes the form of an ellipse surrounding the two suckers. This region changes relatively little in size with growth. In one of the smallest specimens measured (1.6 mm.) the distance between the

[a] During the spring of 1908 two of my students, Messrs. W. N. Anderson and H. B. Boyden, made a study of this form and prepared a partial report on its structure, to which I am indebted for some of the data in the following description, and also for two figures.

centers of the two suckers was 0.5 mm. In one 10 mm. long this distance measured 1 mm.

The posterior region is nearly a perfect cylinder until shortly before the tip, where it tapers somewhat. In some specimens the posterior end is considerably inflated and appears semitranslucent. This is undoubtedly due to the distended condition of the excretory reservoir, which inhibits contraction of the circular muscles in the portion of the skin adjacent to it.

The breadth of the body varies according to the degree of contraction, but may be estimated in general as from 0.7 to 1 mm. An immature specimen 2.85 mm. long measured 0.65 mm. in breadth between the suckers, 0.6 mm. behind the acetabulum, and 0.52 mm. behind the posterior testis. An immature specimen only 1.6 mm. in length measured 0.32, 0.28, and 0.21 mm. in breadth at the same points. In cross section the body is round or very slightly oval.

The oral sucker is subterminal and its opening looks almost directly ventrad. It is rather conspicuous, and in an average specimen measured 0.68 mm. in antero-posterior diameter and 0.67 mm. transversely. The depth in the same specimen was 0.6 mm. The orifice is nearly circular, though often appearing slightly flattened along the posterior margin. In an immature specimen 2.85 mm. long the oral sucker measured 0.35 mm. in antero-posterior diameter and 0.4 mm. laterally; the orifice measured 80 by 150 μ.

The ventral sucker or acetabulum is usually distinctly smaller than the oral. In the extreme case it appears about equal in size or, on the other hand, only about half as large. Ordinarily it is prominent, but in short, thick specimens it is almost hidden, whereas in elongated, slender specimens it projects so far as to appear almost pedunculate. It is also often slightly oval in a transverse plane. In an adult specimen it measured 0.57 mm. in antero-posterior diameter and 0.69 mm. laterally. In a specimen 2.65 mm. long the corresponding measurements were 0.3 and 0.33 mm., and the orifice measured 52 by 80 μ.

The alimentary canal opens in the oral sucker, close behind which lies the pharynx without any prepharynx between the two. The pharynx measures 0.21 by 0.13 mm. It is often seen in the vertical position represented in the figure of Messrs. Anderson and Boyden, which I have taken the liberty of copying here. The œsophagus is very short and it often proceeds anteriad from the upright pharynx, as shown in the drawing (fig. 3, pl. CXXI). At its tip start the two branches of the intestine, which also usually extend forward a short distance and then turning posteriad continue almost to the extreme posterior tip of the body. These crura being longer than the body in the usual specimen are thrown into folds, which often appear as if the canal possessed irregular outpocketings, such as one finds in *Paragonimus*. Observations both on the living material and

on serial sections show positively that such is not the case, but that the crura are simple tubes. The number of folds, twists, and turns depends upon the degree of contraction and usually appears greatest between the acetabulum and the ovary.

The excretory system is very characteristic of the genus *Azygia*. An elongate carrot-shaped collecting reservoir or bladder extends from the excretory pore, which is located at the posterior tip, through the center of the body anteriad to the posterior testis. The wall is heavy and is thrown into folds which appear at intervals projecting slightly into the cavity. From the anterior end of this reservoir two tubes pass off, right and left, which are at the start dorsal to the posterior testis; they soon pass toward the ventral surface, but cross the acetabulum on its dorsal aspect and dorsal to the oral sucker and are reflected posteriad. During their entire course they lie within the intestinal crura and usually ventrad to it. Their heavier walls indicate clearly that these conspicuous tubes are more nearly analogous to the collecting reservoirs of other flukes than to the delicate excretory vessels which here also are seen connecting with the tubes and the reservoir at various points.

The three germ glands, the ovary and two testes, lie close together in a longitudinal row distant from the anterior end about two-thirds the length of the worm. The ovary is most anterior and smallest of the group. An unusual morphological feature is the inclusion of the shell gland, a small yolk reservoir, the ends of the yolk ducts, and the first coils of the uterus within the same capsule that incloses the gland proper (fig. 6, pl. CXXI). The relation of the ducts as worked out by reconstruction is represented in figure 5 after the studies of Messrs. Anderson and Boyden. This resembles closely conditions as shown by Looss (1894) for *A. tereticollis*, although I do not find that he has noted the massing of organs within a common capsule. The uterus extends forward in numerous short coils which all lie within the intestinal crura until at the acetabulum it merges into a short, heavy-walled metraterm. The latter passes dorsal to the acetabulum and ventral to the cirrus pouch into the genital cloaca, with an inconspicuous genital pore located just anteriad to the acetabulum.

The vitelline glands lie along either side of the worm exterior to the intestinal crura. They begin a little behind the level of the acetabulum and extend to a point about halfway from the posterior testis to the end of the body. This constitutes perhaps the most striking morphological difference between this species and *Azygia tereticollis*, in which the vitellaria do not pass posteriad of the posterior testis. This conspicuous difference in the extent of the vitellaria enables the student to differentiate the two forms at a glance.

Attention should be called to the fact that on account of this structural feature a correction must be made in the generic description of *Azygia*, in which

stress was originally laid on the extent of the vitellaria. The condition of the vitellaria in the older species has also been employed by Pratt (1902) as a characteristic of the genus in elaborating his key for the determination of the flukes. Although typically a member of the genus *Azygia*, the present form would fall in another genus according to the terms of that synopsis. No one who sees a specimen or reviews the structure of this form can doubt its relationship; the precise extent of the vitellaria is evidently a subordinate feature, and as such of specific rank only.

The follicles of the vitellaria are distinct, regularly oval bodies, lying in two longitudinal rows on each side with a more or less conspicuous break opposite the ovary between the anterior and posterior series. The follicles measure from 0.06 to 0.07 by 0.03 to 0.04 mm. The symmetry of the rows is in places interrupted by extra follicles, making at such points three rows of follicles instead of two as usual. The ducts from the anterior and posterior series unite opposite the ovary to form a common transverse duct which at the center of the body joins its fellow from the opposite side. At the point of union there is a small yolk reservoir. As already noted, this is included within the common capsule which surrounds the ovary and is ordinarily not visible except in sections. Laurer's canal is present and opens on the dorsal surface just posterior to the ovary. It does not have the enlargement ordinarily called a seminal receptacle, but is usually somewhat coiled and lies on the left side of the ovary. This may be an adaptation to the extreme variations in length so characteristic of this worm.

The eggs are small; an average of 50 measurements places their size at 48 by 27 μ, which is slightly larger and broader than those of *A. tereticollis*, according to the measurements given by Looss (1894).

The testes are oval bodies lying one directly behind the other and that behind the ovary. The three organs are separated only very slightly from each other. The outline of the testes is smooth and measures 0.42 to 0.46 by 0.59 to 0.6 mm. with the major axis transverse. One can usually distinguish that the two are not equal in size. The coiled seminal vesicle and a poorly developed cirrus with prostate lie in a common connective tissue capsule, the cirrus pouch, which stands immediately anterior to the acetabulum. The pouch measures about 0.23 by 0.17 mm. in diameter. It opens anterior to the metraterm into the genital sinus already mentioned.

One histological feature deserves consideration here because of its conspicuous character. In sections of *Azygia sebago* one notices certain muscle elements which are so prominent and regular as to deserve almost the name of a layer; they occur within the parenchyma, far removed from the usually recognized dermal layers and at a point where ordinarily one finds only scattered

dorso-ventral or oblique fibers which are not subject to any regularity in arrangement. These are longitudinal fibers extending from the oral sucker throughout the entire length of the distome, as is clearly seen in a frontal section (fig. 4, pl. CXXI). In position they lie one-fourth to one-fifth the radius of the section distant from the external surface. The cross sections of these fibers show them to be much heavier than the other muscle elements and to occupy an oval zone parallel to the outer surface of the body. They divide the body accordingly into a cortical and a medullary portion. The vitellaria are the only conspicuous organs which lie in the cortical layer. This muscle layer is undoubtedly related to the marked contractions of the fluke which have already been commented upon. Unfortunately I have no material available from which to determine whether similar fibers also exist in *A. tereticollis*. Looss (1904) does not mention them.

The relations of oral sucker, pharynx, and crura, the convolutions of the intestinal branches, the coils of Laurer's canal and of various ducts and the sinuous course of the collecting tubes in the excretory system all point toward the variable extensibility of the worm. Differences in caliber and in the distance between organs also indicate the same. Observations on the living parasite serve to show that it is constantly extending and contracting the body to such an extent as to double or halve the length within a few seconds of time. In fact, I have never before observed a form which indulged in such energetic twisting and contracting. This habit renders any observations on the living worm very difficult.

Looss (1894, p. 7) comments on the active migration of *A. tereticollis* after the death of the host, a feature previously recorded for *D. cylindraceum* by Braun (1890, p. 568). *A. sebago* manifests the same tendency in the most marked degree. The normal seat of this parasite I feel sure is the stomach, and perhaps the œsophagus also, but even a slight delay in the examination of the host resulted in finding single specimens well down the intestine as well as up in the pharynx and even among the gill filaments. In one case a salmon caught late in the day was kept overnight to be photographed, as it was a peculiarly fine specimen. When the viscera were examined, about twenty hours after the capture of the fish, my field notes record that there were 36 distomes in the air bladder and that they were seen coming in through the ostium with mucus from the œsophagus. Other specimens were found in the pharynx and gill cavity and one even in the body cavity. The last can be attributed no doubt to some tear in the alimentary lining which permitted the fluke to make its way unhindered into what is ordinarily a closed cavity. In still another salmon which had gorged itself on smelts my field notes contain com-

ments on the activity manifested by these distomes, which climbed about on the smelts and in them as they lay half digested in the stomach of the salmon.

This was so noticeable that I turned my attention at once to the smelt [a] to ascertain if perchance it played any part in the life history of the distome. In all, I have records of 52 smelts examined, and in 46 of these were found specimens of *Azygia sebago.* The parasite occurred in the stomach only and the infestation was small, from 1 to 14 distomes being found in each host, with an average of only 4 to a fish. In most cases the parasites which were taken from the stomach of the smelt were immature, not having yet reached that size at which the production of ova begins; they were on the average 3 to 4 mm. long, or in some cases even smaller, running from 1.5 to 2.5 mm. in length. Single specimens reached a length of 6, 7, and even 10 mm. In one case, indeed, there were none shorter than 6 mm., and the specimens varied from that to 10 mm., so that one can not fairly maintain that they never reach the size attained in the salmon. Nevertheless, after the account is cast up the average shows distinctly that the distomes do not reach their full size in the smelt and, so far as collections made during July and August can indicate, those taken from this host are usually small in size and sexually immature. I did not obtain any information as to the source from which the smelt acquires its infection, but in view of the universality with which smelt form the food of the salmon in Sebago Lake the latter undoubtedly owe to them the major portion of their infestation with this parasite.

The host record of *Azygia sebago* is even yet unfinished. In the course of my work numerous other fish from these same waters were examined. In young specimens of *Esox reticulatus* 6 to 16 inches long I found this same parasite reasonably abundant. To be sure, they seemed to average somewhat longer, being 10 to 12 mm. in length in material from one host and 10 to 14 or even 18

[a] This fish I am compelled to designate under the name *Osmerus mordax* (Mitchill), as Jordan and Evermann (1896) do not recognize the Sebago smelt as a separate form, saying of the species "Atlantic coast of the United States from Virginia northward to Gulf of St. Lawrence, entering streams and often landlocked." I am inclined to think that even in Sebago Lake there are two smelts. My attention was first directed to this possibility by Dr. W. C. Kendall, who, recalling our previous discussion, writes as follows in a recent letter:

"You may recall that there seem to be two forms in the lake differing somewhat in size and habits. The large form, which is the one that we caught with hook and line, is nearer to the marine smelt. The small form is the one that we found in the salmons' stomachs. You will doubtless recall that the principal food, when any at all was found in their stomachs, of the large form was small fish, generally young smelts. Our examinations of the stomach contents of the small form show Entomostraca almost exclusively. This difference is indicated also by the gillrakers, which are more numerous in the small form."

These distomes occurred equally in both sorts of smelt and those from the smaller smelts were larger than those from the larger fish. This is, of course, a mere accident, but it serves to show that the two types of smelt conduct themselves alike toward the parasite.

mm. long in that from another host. In the latter it was noticeable that the suckers protruded very conspicuously and the body was much smaller in caliber than in the specimens from the salmon and the smelt. Yet in the absence of any structural differences I am forced to conclude that this contrast in size and general external appearance is due to some slight difference in the technique employed or in the condition of the parasites when they were preserved. This is all the more probable when one considers that in one case the specimens from *Esox* were identical in appearance with those from the salmon. This parasite was found in all but one of the dozen specimens of *Esox reticulatus* examined, being present in the stomach in numbers of 1 to 80 in each host. In two cases a single specimen was found in the intestine, perhaps due to some post-mortem wandering on the part of the parasites. In 4 specimens of *Anguilla chrysypa* out of 9 examined I also found *Azygia sebago* in the stomach, but in small numbers only, averaging 3 to each host. Finally 2 of these distomes were found in a single *Perca flavescens*, here also in the stomach.

In order to give a ready comparison, I append hereto a table of similar measurements from a series of this distome taken from the various hosts mentioned. The difference in length indicates in part age and in part method of preservation. In fact, it is difficult to achieve any uniformity among specimens so exceedingly active as this species.

MEASUREMENTS OF AZYGIA SEBAGO.

Serial No.	Host.	Length.	Anterior tip to center of oral sucker.	Diameter of oral sucker.	Distance between centers of suckers.	Diameter of acetabulum.	Anterior tip to center of ovary.	Distance between center of ovary and anterior testis.	Distance between centers of testes.	Distance from posterior testis to posterior tip.	Breadth between suckers.	Breadth behind acetabulum.	Breadth behind posterior testis.
		Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
16	From Salmo	8.75	0.31	0.74	1.38	0.65	4.76	0.31	0.62	3.07	1.29	1.38	1.23
74–79	From Osmerus	2.85	.16	.4	.62	.33	1.6	.12	.12	1	.65	.6	.53
60	do	1.64	.1	.25	.4	.2	.89	.1	.1	.55	.32	.28	.21
96	do.[a]	7.85	------	.56	------	.37	------	------	------	------	.28	.31	.25
7–8	From Esox	12.6	.38	.72	1.84	.55	7.88	.9	.91	3.25	.75	.77	.74
46	From Perca	4.08	.29	.51 by .57	.78	.35 by .4	2.69	.15	.19	1.16	.71	.77	.55

[a] Much elongated; poor technique; preserved by helper.

The question naturally presents itself, Has this form been seen by others previous to the present date? The records on the subject are scanty, but they throw some light on the question.

Leidy has described (1851, p. 206) a form as *Distomum terreticolle*[a] Rudolphi, which Pratt (1902, p. 957) lists as *Azygia tereticollis* (R.) Leidy. The original description is as follows (Leidy, 1851, p. 206):

Distomum terreticolle, Rud. Entoz. Syn., p. 102; Dujardin, Hist. Nat. des Helm.; Diesing, Syst. Helm., p. 358.

Body subcylindric, light flesh color, posteriorly rounded. Ventral acetabulum (¾ line) 1.6 mm. behind the oral (⅓ line) 0.7 mm. in diameter. Oral acetabulum (¼ line) 0.5 mm.

Length (8 lines) 16.8 mm.; breadth posteriorly (½ line) 1 mm., anteriorly (⅓ line) 0.7 mm.

Habitation.—Stomach of *Esox reticulatus* Lesueur.

Remark.—The generative aperture is placed immediately in advance of the ventral acetabulum. When the animal contracts, the two acetabula are nearly brought into contact.

The description is scanty, and yet one can say with some assurance that the form before Leidy was not the European species named by Rudolphi and discussed by a long series of authors, of whom Looss (1894) has given the most complete description with truly admirable figures. Leidy's specimen is much too small for average adults of *Azygia tereticollis*, which is, moreover, cylindrical instead of broader posteriorly, as was Leidy's worm. Again, *Azygia tereticollis* has the oral sucker larger than the acetabulum, whereas in Leidy's form the reverse is true. Finally the suckers in Leidy's form do not agree at all in size with the suckers in *Azygia tereticollis*, as described by Dujardin and others.

It is somewhat more difficult to say whether the form before Leidy was the same as that I collected in the Sebago salmon. In size the two are not very different, although Leidy's was larger. Other measurements do not agree at all well. The sizes given for the suckers are just about reversed. The final determination of this point, however, must await a reexamination of Leidy's original material.

The only other reference to the occurrence of *Azygia* on this continent, so far as I know, is the brief note of Stafford (1904, p. 488), in which he records *Azygia*[b] *tereticollis* Rudolphi from mouth, pharynx, œsophagus, and stomach of *Esox lucius* Linnæus, *Lota maculosa* Le Sueur, and *Ameiurus nigricans* Le Sueur. Absolutely the only data concerning the worm which Stafford records is the size, 12 by 1 mm. Now, this does not agree with adults of *A. tereticollis*, for Looss (1894, p. 18) says of that species that the first eggs are not set free into the uterus until the worm is 8 to 10 mm. or more in length, and these are uniformly abnormal and defective. In another place he remarks (1894, p. 7) that in most cases eggs are found in worms 12 mm. long, although in scanty numbers. I am of the opinion that Stafford did not have before him the true *A. tereticollis*

[a] The text by error contains *terreticolle* for the specific name instead of *tereticolle*.

[b] Unfortunately, Stafford spells the genus *Azigia* and the species *tereticolle*.

and incline to the belief that the form which he observed may have been the species under discussion.

The European species, *Azygia tereticollis*, has been reported from *Esox lucius*, *Lucioperca sandra*, *Lota vulgaris*, *Trutta variabilis*, *Salmo trutta*, *Salmo fario*, *Salmo hucho*, *Salmo alpinus*, and *Salmo salar*. All of these save *Salmo salar* are fresh-water fish, and the parasite may be regarded as a characteristic of fresh-water species. The American species, *Azygia sebago*, I found in *Salmo sebago*, *Esox reticulatus*, *Osmerus mordax*, *Anguilla chrysypa*, and *Perca flavescens*. Stafford recorded what may have been the same from *Esox lucius*, *Lota maculosa*, and *Ameiurus nigricans*. These include strictly fresh-water forms, landlocked species, and one migratory fish, but inasmuch as the records have been taken in fresh water even the last host does not constitute any evidence against the fresh-water habitat of *Azygia sebago*. Its congener, *Azygia tereticollis*, found by McIntosh in the salmon of the Tay, formed part of the evidence that this host feeds during its fresh-water residence. Equally here we may regard *A. sebago* as a fresh-water element acquired by its host since the latter became landlocked in Lake Sebago. The presence of the parasite in several other characteristic fish of the same water basin is clear evidence of the sources from which it might have come.

CESTODES.

Cestodes constituted the most conspicuous element of the parasitic fauna. Every salmon opened contained a mass of large worms in the pyloric region. They lay with the head and anterior portion of the body in a pyloric cœcum usually at or near its tip. The worms were large and the body was thrown into loops which occupied the initial cœcum and folded through the intestinal canal into other cœca, often crowding them full apparently to bursting. Viewed from the body cavity, even before the viscera were opened, one could distinguish the cœca which contained the parasites by their opaque, chalky appearance in distinct contrast with the translucent character of those cœca in which there were no tapeworms. When the intestine was opened it appeared full of the cestodes, which protruded in loops hanging from the cœca into the cavity or crossing into other cœca in a tangled mass, in several cases large enough to distend the wall conspicuously. The anterior cœca were those primarily or chiefly occupied by the worms and although often the entire cavity of the intestinal canal was crowded full of parasites, it was noteworthy that they rarely if ever entered any of the posterior cœca. When few worms were found they lay with the scolices at least in the cœca of the most anterior region.

The species to which I have referred in the preceding paragraph is the well-known *Bothriocephalus infundibuliformis*, according to Lühe (1899) more correctly designated *Abothrium crassum*, which is so common in the Atlantic salmon

from various parts of Europe. Of its occurrence in the Rhine salmon, where it is found in 42 per cent of the specimens examined, in 91 per cent of the Baltic salmon, in 26 per cent of the Tweed salmon, in most of the Tay salmon and of the Irish salmon, enough has been said in the historical survey. It is a typical salmonid parasite, and is found even in eight species of that family which inhabit fresh water. Its presence in the landlocked *Salmo sebago*, which confines its life cycle to fresh water, is hence not surprising. Evidently the life cycle of the species permits of easy adaptation to a fresh-water existence, for I have to report its occurrence not only in the host under discussion, but also in another prominent American salmonid, the Great Lakes trout, *Cristivomer namaycush* (Walbaum). It was found abundantly in specimens of this host which I examined in July and August, 1894, at Charlevoix, Mich. From 30 to 80 tapeworms of this species were present in each Sebago salmon, and neither size nor age played any evident part in determining the degree of infestation. Absolutely every one of the salmon taken was infested. In considering the possible life history, I naturally turned to the Sebago smelt as the host of the larval form, probably a plerocercoid, and examined a number of these fish with great care, but was unable to detect the larva, if indeed it was present. Nothing was discovered which throws any light on the life cycle. It is worthy of note that all of these parasites were full grown; not a single specimen was found which was not discharging ripe proglottids. Consequently the infestation must have taken place somewhat earlier in the year. It would take observations at other months to determine when; and the food at that time would evidently be the source of the parasite.

In addition to this dominant species some other cestodes were also recorded. A few fragments of a small species of *Proteocephalus* were found in each of four hosts, and a larval form, which probably belongs to the same *Proteocephalus*, was obtained in each of two hosts. Two different bothriocephalid larvæ of small size also occurred each in a single salmon. The four forms just mentioned were all found in the intestine.

The insignificant size of a new species of *Proteocephalus* found and the small number of individuals present in any one host resulted in its being overlooked at first, and it may easily have been present in more hosts than shown by the records. It was found in four out of the seven salmon examined, but in one case only a few loose proglottids were discovered by accident among material from the intestine. A careful examination in comparison with the descriptions of known species leads me to the view that this is a new species to which the name *Proteocephalus pusillus* may be given. The salient points in the description of this new species are as follows:

Proteocephalus pusillus nov. spec.—Adult cestode with short strobila, measuring only 30 to 50 mm. in length. Proglottids scanty, segmentation

distinct. Head much contracted. Neck 1 to 1.5 mm. long by 0.21 mm. broad. First proglottids 0.09 mm. broad, changing gradually until in mature proglottids the length greatly exceeds the breadth. Ripe proglottids measure 0.84 to 1.4 mm. long by 0.18 to 0.35 mm. broad. Terminal proglottids present and fertile. Sexual organs typical for *Protcocephalus;* uterus median, with 10 to 14 lateral outpocketings on either side. Testes numerous, within vitellaria. Genital pore lateral, one-third to two-fifths of length of proglottid from anterior margin of same. Ovaries bilobed, median isthmus indistinct, anteroposterior diameter nearly equal to breadth of both lobes. Only a few specimens obtained from a single host species, *Salmo sebago.*

This species approaches most nearly to *P. ocellata* and *P. percæ* among known species. Unlike the new species, however, both of these older forms have a fifth sucker, fewer lateral uterine outpocketings, a longer neck, differently shaped ovaries, and markedly different proglottids.

In specimens with developed proglottids the head was so much contracted or distorted that any special description would be of little value. One could easily observe the general features characteristic of the genus. There was no well developed terminal or fifth sucker, and the end organ, which is known to replace it in many forms of this genus, was inconspicuously developed, if present. Personally, I incline to the view that on more careful examination this structure will be found in all species, even those in which its absence has been made a matter of record. Accordingly, not much weight can be put in its presence or absence in any individual case.[a]

Three plerocercoid larvæ or young cestodes were found in company with *Protcocephalus pusillus*, which I regard as young forms of this species. The largest came from the salmon which was most heavily infected with this cestode parasite. It was 3.15 mm. long and had begun to assume clearly the appearance of an immature cestode. The head measured 0.3 mm. wide by 0.26 mm. long, and the suckers 0.14 mm. in length by 0.11 mm. in width. The neck was slightly narrower than the head, but was not clearly set off from the body, which was very uniform in diameter and measured 0.25 mm. in average width. The posterior end of the body was swollen into a rounded knob about 0.35 mm. broad and of approximately the same length. This feature was evidently produced by a powerful contraction of the terminal region of the body. In and near it one could see very indistinct indications of proglottid formation. In form, size, and general aspect this young cestode was in full agreement with the anterior regions of the mature cestodes of this species with which it was

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[a] For a more definite discussion of this peculiar structure so variable in development in the cestodes of this genus, I would refer to a paper now in press by my student, Mr. George R. La Rue, to whom I am indebted for a comparison of this material from *Salmo sebago* with preparations of other species of *Proteocephalus*

associated. The head, which was not contracted, showed on careful study the delicate outline of a rudimentary end organ. While such a structure was not demonstrated in the mature individuals described above, one can say positively that if present it could not have been seen owing to the greatly contracted condition of the adult scolices. I believe that its presence will be demonstrated in more favorable specimens. The complete agreement of this largest larva with the mature specimens in all other features compels me to regard both as different stages in the development of the same species.

The other larvæ were still in early stages of development, and probably had been ingested by the salmon at a very recent date. Their relationship is not so clear in all respects, and yet I do not hesitate to associate with the new species of *Proteocephalus* a plerocercoid or young cestode obtained from the same host as the adult worms and the older larva just described. The head is broadly conical, without furrows, and measures 0.3 mm. in breadth. The suckers measure 60 to 75μ in diameter. There is no rostellum or fifth sucker to be found, while the end organ is so poorly developed as to be visible with difficulty and only under the most favorable circumstances. The neck is nearly as broad as the head. In general appearance this larva resembles the adult cestode and the older larva previously described. With some reserve one may also assign to this species a single plerocercus taken from another specimen of *Salmo sebago*. The head, which measures only 150μ in breadth, is shaped like that of the young cestode and like it is without rostellum or fifth sucker, while the end organ is difficult to demonstrate. Neither furrows nor ridges are seen on the larva, which has a total length of 1.14 mm. The sucker measures only 30 to 45μ in diameter. The neck is slightly narrower than the head. This form certainly belongs to the genus *Proteocephalus* and probably to the species already described.

From the scantiness of the material obtained one might infer that the Sebago salmon is only a casual host of the species. Yet I did not secure this parasite from any other fish in Lake Sebago and adjacent waters, and I have not met it in fish examined in other places. The presence of larvæ in different stages of development with only a few adult specimens in any one host, although some were found in the majority of the salmon examined, would rather favor the view that the cestode was a regular though infrequent parasite of this host.

Sparganum sebago, nov. spec.—In addition to the cestodes already mentioned, there are to be noted two specimens of bothriocephalid larvæ which deserve more extended mention.

The first was taken from the spleen of one salmon. It measured 25 mm. in length and 1.8 mm. in maximum diameter. There is no neck, but the body

increases slightly in breadth for about one-quarter of the entire length and then tapers gradually to the posterior end, which is rounded off. The body is elliptical in cross section without any segmentation, but with numerous rather prominent annular wrinkles. It seemed as if the margins of the body were thicker than the center. The head was retracted. (Fig. 7 and 8, pl. CXXI.)

The second specimen (fig. 9 and 10, pl. CXXI) was found free in the body cavity of another salmon. It was 36 mm. long and 0.86 mm. in breadth. The body was somewhat thicker than in the other specimen, but less deeply wrinkled, and the center was certainly thicker than the margins. In this, as in the color and texture, it appeared different from the first specimen. There was no neck. The head measured 0.31 mm. in transverse diameter and 0.43 mm. from the apex to the base of the grooves, which were keyhole shaped. The groove measured 0.25 mm. in transverse diameter at the anterior end and 0.09 near its posterior end. In spite of the differences in appearance noted above it is easily possible that the two specimens belong to the same species and I have preferred to list them for the present under a single heading, naming the form *Sparganum sebago*.

A word should be said with regard to other hosts for these cestodes. *Abothrium crassum* was not found in any other fish examined at Sebago Lake. Larvæ of *Proteocephalus* and of some bothriocephalid were found in a very few cases in other fish taken from these waters. There were none, however, of which it could be said with reasonable certainty that they were the same as the forms collected from the Sebago salmon and mentioned above. The question of the occurrence of such salmon parasites in other hosts of this region must be left entirely open for the present at least.

NEMATODES.

Nematodes were not common. They occurred only in half of the specimens of salmon examined and were not abundant. In one salmon 33 of these worms were obtained, but in the other three only a dozen all told. Accordingly they seem to play only a minor part in the parasitic fauna of the Sebago salmon. They belong to two or three separate species, which are radically distinct. Thus far I have not been able to make a satisfactory determination for any of them, owing to the scantiness of the material and to its unsatisfactory condition. This much can be said: They do not belong to any of the species, or even to the genera, heretofore recorded for the Atlantic salmon. A few notes may be added here concerning these forms.

A small nematode was found in the stomach and in the body cavity of two salmon. In all there were only six individuals of this species. I have not been able to satisfy myself that the individuals recorded as from the stomach really belong there, but incline to think that they were adherent to the external

surface of the stomach and passed unnoticed when that organ was opened and shaken in a preserving fluid in order to collect the small specimens of *Azygia sebago* concealed in the gastric mucus. Subsequently they were found in the material obtained in this process. They are probably true parasites of the body cavity. Since an approximate determination may easily be misleading I forego all attempt to name this form and designate it for the present simply as "Nematode A."

The group of 33 nematodes obtained from the body cavity was a source of great surprise. These worms are identical with a form found in very large numbers in the Alaska salmon. Since, however, this species is to be discussed at length in the section of my report which deals with that host, it seems wise to omit here any details and refer to the worm simply as "Nematode B." It is a large form belonging to the Filariadæ, but so delicate that it is almost impossible to obtain perfect specimens, and it has thus far proved beyond my skill to preserve any in a complete condition. It has been an exceedingly interesting object of study and will receive at an early date, in connection with the records of the Alaska salmon and its parasites, that detailed consideration which its frequence and its interest warrant. The six nematodes recorded from the stomach were collected and preserved by an assistant. They are in very poor condition, so that any determination can hardly be more than an impression, but the only real reason why I hesitate to refer them to the same species is that in all the thousands of specimens from nearly 200 hosts which I handled in the course of my investigations on the Alaska salmon I never once found the species anywhere save in the body cavity. It is not impossible that these specimens were reported from the stomach through some error. As repeated examination is bringing me more and more firmly to accept the identity of this lot with those which I collected personally from the body cavity of the Sebago salmon and of the Alaska salmon, I am being forced to assume the existence of some error in recording them as from the stomach.

In any event, it may be said that not more than three species of nematodes are present in the Sebago salmon and that these species are only infrequently and scantily represented in this host. None of the nematodes were found in any other fish examined at Sebago Lake, nor are they known to me from fish of any fresh-water locality in this country. Thus far also I have failed to find any reference in the literature which could be construed as indicating either of these forms.

RÉSUMÉ AND CONCLUSIONS.

The first general conclusion to be drawn from this study of the parasitic fauna of the Sebago salmon is that the total number of parasites recorded from this host is small. In all, there have been listed only 1 trematode, 2 cestodes, 4 (?) cestode larvæ, and 2 nematodes, or a total at most of 9 species

of parasites. To be sure, the number of hosts examined was small, and this may account for the low total record. Two of these parasites, *Azygia sebago* and *Abothrium crassum*, were found in every fish examined, and each of six other parasites was found in two hosts. This may be compared with Zschokke (1896, p. 824), who records the parasitic census of 10 salmon from the North Sea. In these 10 fish were found 10 species of parasites. A trematode and a cestode occurred each in 9 of the fish examined. The cestode was *Abothrium crassum*, the same species as that found in every Sebago salmon; the trematode was *Distomum ocreatum*, a purely marine form, and hence in sharp contrast with the abundant trematode in the Sebago salmon, which is a member of a characteristic fresh-water genus. This contrast, as well as several other details commented on in the previous pages, seem to indicate the fresh-water aspect of the parasitic fauna in the Sebago salmon.

The conditions in the Sebago salmon are all the more striking when one considers the forms which are not found among its parasites. Reverting first to the trematodes, one notices that the only genus represented here, *Azygia*, has been recorded from the Atlantic salmon in Europe only in a single case, while here its representatives were found in every host examined. On the other hand, *Derogenes varicus*, recorded from a good percentage of European salmon in all localities, was not seen even once. The other distomes recorded by European observers in various regions, and often as fairly frequent parasites of the salmon, are entirely wanting in Sebago salmon. *Azygia* is the only purely fresh-water distome found in European salmon; it is the only distome found in the Sebago salmon. The other distomes recorded in European salmon are purely marine species, or very largely so, but none of them occur in the Sebago salmon.

Among the cestodes conditions are identical. The common form, *Abothrium crassum*, is confined to salmonids, without reference to their habitat, and is as common in fresh-water species as in marine. On the other hand, those cestodes which are typically marine, like *Rhynchobothrium paleaceum*, *Scolex polymorphus*, and the several species of *Tetrarhynchus*, are absolutely wanting in the Sebago salmon. The various cestode larvæ are too little known to justify their consideration in this connection. They are not referable, even indefinitely, to either habitat. To this statement one must make two exceptions. *Scolex polymorphus*, recorded from the salmon in Europe, is typically marine, occurring in many sea fish, even though several species may be indicated under the single name. On the other hand, the larva of *Proteocephalus* is equally typically limnetic and it is recorded from the Sebago salmon only unless the single record of *Tænia* sp. for a larva from the salmon in the Tweed should be referred to this form. In this group again it appears clear that the marine parasites of the European salmon are wanting in the Sebago species, that the only cestodes

identical in the two forms are such as are clearly fresh-water species, and that the Sebago salmon contain at least one clearly fresh-water genus which is not reported from the corresponding European host.

Among the nematodes the evidence is less conclusive, since the amount of material is smaller; indeed, hardly enough to form a basis for any conclusions. At the same time, all the species which give to the parasitic fauna of the European salmon its marine aspect are entirely wanting here. Not a single specimen of *Agamonema* was discovered, although two species are found in the European salmon, and one of them, *Agamonema capsularia*, is very common. Both *Ascaris* and *Echinorhynchus* are unrepresented in the parasitic fauna of the Sebago salmon. Among the numerous species of each already recorded as parasitic in the European salmon three out of four are purely marine. Here again one notes that the marine elements in the parasitic fauna of the European salmon are wanting in the Sebago salmon. Possibly the large filariad found abundantly in the Alaska salmon, and reported also from one or two salmon taken in Sebago Lake, forms an exception to the general rule. As I have already noted, it appears to be marine in origin. This may be, however, a false argument, and the species may actually be one limited to this host or to the salmonid family, regardless of habitat. In this connection one naturally recalls at once the case of *Abothrium crassum*, which, from the observations on salmon in the North Sea and then in the Rhine, might be said to be a marine form, since it gradually disappears on the journey up the Rhine. But it occurs in hosts of purely fresh-water habitat, such as *Salmo hucho* in Europe and *Cristivomer namaycush* in the Great Lakes of North America. Evidently further information is needed before one can safely assign this nematode to a definite habitat.

Summing up all the evidence concerning the parasites of the Sebago salmon, one finds that four species are unknown in character, one only is possibly marine, one is a pure salmon parasite, and three are clearly fresh-water forms. The latter are also its most frequent and numerous guests. Furthermore, the Sebago salmon lacks every one of those parasites found in the European salmon which must be regarded as purely or largely marine, and possesses in common with its European congener only one characteristic salmon parasite and possibly also two fresh-water forms, which, though abundant in its own parasitic fauna, are very rare in that of its relative.

The parasitic fauna of the Sebago salmon manifests a striking fresh-water aspect, all the more unexpected in view of the marine character of that in the European salmon as demonstrated by Zschokke. One could hardly find a more convincing demonstration of the fundamental biological relation between parasite and host.

The parasitic fauna of any animal is primarily a function of its habitat.

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EXPLANATION OF PLATE.

FIG. 1. *Azygia sebago.* Group of individuals from *Salmo sebago*, after preservation in corrosive sublimate and then alcohol. ×2.

2. *Azygia sebago.* Specimen from salmon, stained and mounted in balsam. Dorsal view. ×12½.

3. *Azygia sebago.* Anterior region of alimentary canal in lateral aspect. Reconstruction by Messrs. W. M. Anderson and H. B. Boyden. *in*, intestine; *œ*, œsophagus; *os*, oral sucker; *ph*, pharynx. Highly magnified.

4. *Azygia sebago.* Longisection showing relations of principal organs. *exc*, main excretory vessels; *lpm*, longitudinal parenchym muscles, for explanation of which compare text; *vit*, follicles of vitellarium. Camera drawing. ×358.

5. *Azygia sebago.* Female reproductive system in dorsal aspect. Semidiagrammatic to show relation of organs in ovarial complex. *lc*, Laurer's canal; *od*, germ duct; *ov*, germarium; *sg*, shell gland; *ut*, first coils of uterus; *yd*, transverse vitelline duct; *yr*, yolk reservoir. After reconstruction by Messrs. Anderson and Boyden. Highly magnified.

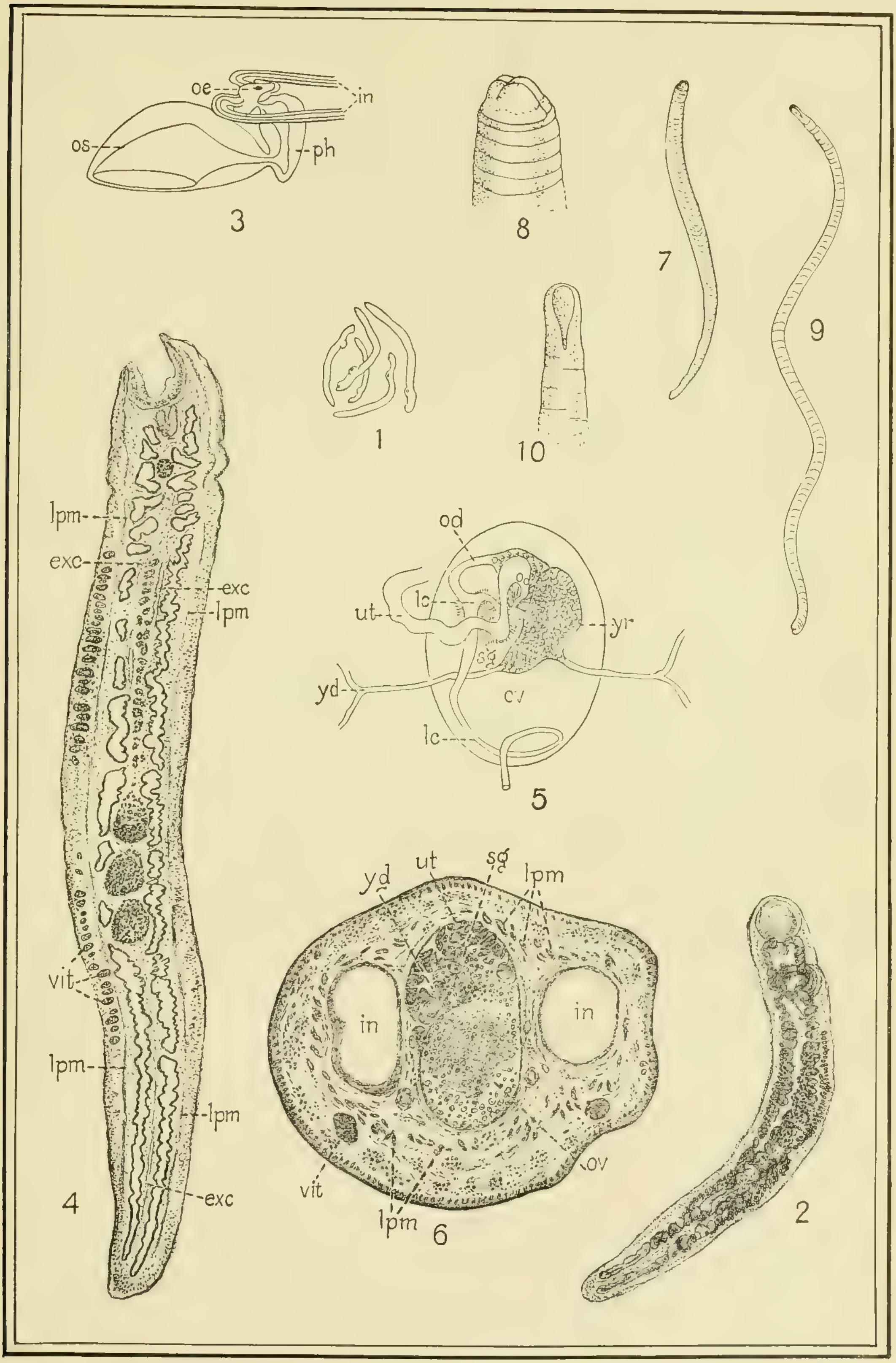
6. *Azygia sebago.* Transsection through ovarial complex, showing relations of organs to common capsule (see text). *in*, intestinal crura; *lpm*, longitudinal parenchym muscles; *ov*, germ gland; *sg*, shell gland; *ut*, first coil of uterus; *vit*, follicle of vitellarium; *yd*, common yolk duct and part of yolk reservoir. Camera drawing ×60.

7. *Sparganum sebago*, nov. sp. Bothriocephalid larva from spleen of *Salmo sebago.* Drawn from alcoholic specimen. ×2.

8. Head of larva, shown in fig. 7 ×25.

9. *Sparganum sebago*, nov. sp. Bothriocephalid larva from body cavity of *Salmo sebago.* Drawn from alcoholic specimen. ×2.

10. Head of larva, shown in fig. 9. ×25.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NOTES ON THE FLESH PARASITES OF MARINE FOOD FISHES

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CONTENTS.

	Page
Introduction	1197
Principles of distribution of entozoa	1198
Zoological orders represented by flesh parasites of fishes	1198
Sporozoa	1198
Nematoda	1199
Trematoda	1199
Cestoda	1200
The case of the butterfish	1202
General considerations as to flesh parasites of fishes	1206
Tabulated results of examinations	1208

NOTES ON THE FLESH PARASITES OF MARINE FOOD FISHES.

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INTRODUCTION.

In beginning the study of fish parasites it was soon realized that by far the most likely place to find entozoa is within the body cavity of the host. Often, therefore, on account of the abundance of material and the limited time at my disposal, I confined my collecting almost wholly to what could be secured from the alimentary tract and the body cavity. An occasional search for parasites in the flesh of marine fishes met with so few finds that it came to be in large measure neglected. In 1904, however, I discovered that the parasitism which I had already noted in the case of the butterfish (*Poronotus triacanthus*), instead of being of occasional and accidental occurrence, is really of almost universal prevalence in all localities where I have studied this fish.

The results of my investigations on the butterfish parasite naturally suggested inquiry as to the condition in this particular of other food fishes, and it is the purpose of this paper to set forth some of the results of my investigations of this subject. In the summer which has just passed (1908) I spent three weeks at the laboratory of the Carnegie Institution at the Dry Tortugas, and the remainder of the time at the laboratory of the Bureau of Fisheries, Woods Hole, Mass. Most of the fishes that I examined were examined for flesh parasites, and, with one or two exceptions, this paper is confined to results obtained in the present season. This applies more especially to the tabulated results.

The results of this study are as yet very uneven; at the same time they afford certain conclusions which are of importance, as will appear in the progress of the paper. It may be stated properly in this connection that while very few, or even in some cases only one, example of a species of fish was examined, the general results of this past summer's investigation are in agreement with those of previous years—namely, that the marine food fishes, with the exception of the butterfish, are singularly free from parasites in the flesh. Indeed, with the exception of the butterfish, I have not yet found any one of our food fishes which is more than an accidental intermediate host for any parasite. At least, if there are any such they are confined to those cases in which the walls of the alimentary tract furnish a lodgment for various cestode cysts.

The method employed in the examination of the flesh for parasites was the same I have used in examining butterfish in previous years. The fish were split open longitudinally and the flesh separated from the backbone and vertebral spines. Occasionally the flesh was further divided. This method exposes the usual location of flesh parasites.

PRINCIPLES OF DISTRIBUTION OF ENTOZOA.

In order that the subject-matter of this paper be perfectly clear, it is necessary to give a brief résumé of the principles which determine the distribution of the entozoa. The term "entozoan" is a convenient general designation for any animal which lives within another animal. The adult egg-producing animal lives in the alimentary tract, or some part in direct connection with the alimentary tract, as the bile duct, or, in the case of air-breathing animals, also in the air passages. As a rule the eggs, or in the case of the cestode or tapeworm the ripe joints, which separate from the parent chain, are thrown off with the natural discharges of the animal in which they are living. The animal which harbors the adult tapeworm is called the final host. In order to develop, the eggs, as a rule, must enter the alimentary tract of another animal. In this animal the eggshell is digested off and the minute embryo thus liberated penetrates the mucous membrane of this second or intermediate host and sooner or later comes to rest. A cyst of connective tissue is formed around it by the tissues of its host. In this cyst the parasite remains quiescent, and ordinarily this is the end of the individual unless it is swallowed by the animal in whose alimentary canal it can become sexually mature. In this case another generation of eggs is produced and the round of life from egg to egg again is completed.

In the majority of instances a cestode egg gives rise to but one adult chain. In a few instances a large number may develop from one egg, on account of the multiplication of larvæ by a kind of budding in the encysted stage. So far as I have observed, there are no examples of this latter method of reproduction among the cestodes that infest fishes.

ZOOLOGICAL ORDERS REPRESENTED BY FLESH PARASITES OF FISHES.

The following groups are represented in the parasites which I have found in the flesh of our marine food fish:

SPOROZOA.

These protozoan parasites occur in small white cysts, usually along the backbone of small fishes. They seem to be of rather common occurrence in young alewives and herring.[a] I have not examined many full-grown herring

[a] Linton, E.: Parasites of fishes of the Woods Hole region. Bulletin U. S. Fish Commission, vol. XIX, 1899, p. 438, 439.

and alewives, but, so far as my researches have gone, the flesh parasites appear to be confined to the young fish. It seems probable that the badly infected young do not reach maturity. Our knowledge of the life cycle of the sporozoa is very fragmentary, and it is perhaps better to expend our energies in the accumulation of knowledge, even if it must consist largely of apparently unconnected facts, than to attempt to explain what further investigation may show in a clear light.

NEMATODA.

While immature roundworms are very common on the viscera of fish, they are, fortunately from our point of view, of exceedingly rare occurrence in the flesh of marine fish. I have not found them in the flesh of any of the fishes which are strictly food fish at Woods Hole, Beaufort, or Tortugas. In Bermuda I found numerous roundworms (*Ichthyonema globiceps*) in the flesh of a gar (*Tylosurus acus*). These were colored blood-red and lay in tangled clusters in the flesh, most abundant near the backbone. They bore a close resemblance to blood vessels. I have occasionally found this species, or a species near it, in the ovaries of some of our food fishes. If these were of common occurrence the fact would be somewhat disturbing. The worms are long and thread-like, often growing to the length of several inches. They are, moreover, crowded either with ova or, in most cases, with the young. The latter are very minute, but very active, and are in vast numbers. What would be the result if eaten in insufficiently cooked food is not known. If, like the dread *Trichina*, they can resist the digestive juices of the human stomach, they might easily penetrate the mucous membrane and, carried by the blood, finally lodge in congenial tissues of the body, to become encysted, provided the body is able to stand the inflammation produced by the invasion.

Nematodes are very resistant to digestive fluids and are much more to be feared than either trematodes or cestodes. In addition, they are nearer the popular conception of the word worm than representatives of other orders of the helminths. It is, therefore, a satisfaction to state that the probability of consuming nematodes along with our fish food is very slight, indeed, and in no way to be compared with the like probability in the eating of pork.

TREMATODA.

While this order of flat worms has a very large representation among the species of entozoa inhabiting fish, their occurrence in the flesh of marine fish is extremely rare, so much so that the few cases which I have recorded must be regarded as accidental. The only cases where members of this order are at all likely to enter our alimentary canals along with our fish food will be as skin parasites. Many fish, especially tautog, cunner, and, to a lesser degree, flounders,

tomcod, and fish of similar habits, have small distomes encysted in the skin and in the fins. As these are almost always all removed in preparing the fish for cooking, they need cause no more thought, even to the ultra fastidious, than other accidental débris that may be caught by the slimy epidermis of the fish. On fishes inhabiting small fresh-water lakes this form of parasitism is common. The bearer of the adult stage of these skin parasites is commonly some fish-eating bird.

CESTODA.

This order is represented by many genera and species among the entozoa of marine fishes. The sharks and skates harbor a long list of adult cestodes in their alimentary canals, especially in the intestine or spiral valve. The mature joints of these cestodes, each filled with hundreds, even thousands of eggs, are cast into the water in vast numbers along with the fæces of the host. It is a peculiarity of these free segments that they may continue living for some time, even many hours, in sea water. In the water they are likely to be eaten by such fish as feed on small worms, crustacea, and the like. The adult stage of any of these cestodes of the sharks and skates is limited to a few closely related species, or, in some cases, apparently to a single species. They are, on the other hand, capable of living on a large number of intermediate hosts. A little reflection on the contrasted conditions to which the adult and the larval stages, respectively, of a cestode are subjected will serve to explain this difference.

In the adult stage the cestode passes its whole existence in the alimentary canal of its host. It has become adapted to a highly specialized set of conditions. Hosts differ specifically not only in respect to their morphological characteristics but in their physiological characters as well. Thus a given cestode may find the juices of the alimentary canal of a tiger shark kindly while it finds the juices of the alimentary canal of any other shark fatal to its development. There is also some difference in the character of the food. The latter might seem to account for the difference between the parasites of a shark whose diet consists mainly of crustaceans, and one which has a strictly fish diet. On the other hand, sharks which feed on practically the same food, if they are not closely related morphologically, may be found to harbor a different set of cestode parasites. For example, the entozoa of the dusky shark (*Carcharhinus obscurus*) and those of the blue shark (*C. milberti*) comprise practically the same species. When the list from either of these sharks is compared with the list from the sand shark (*Carcharias littoralis*), some constant differences at once appear. There is one species of cestode (*Crossobothrium laciniatum*) which is almost invariably present in the sand shark and usually in considerable numbers. It has not been found in any other species of shark or skate. Furthermore, very few of the long list of cestodes from the dusky shark have been found in the sand shark.

When we turn to the intermediate hosts of these cestodes we find no such limitations. For example, there is a cestode (*Tetrarhynchus bisulcatus*) which is of common occurrence in the dusky shark in the Woods Hole region. I found the same or a closely related species in a shark, which was rather doubtfully identified as a blue shark, at Beaufort, and two specimens, not yet mature, in a sharp-nosed shark (*Scoliodon terræ-novæ*) at that place. This cestode may be said to be practically limited to the dusky shark as its final host. I have found it encysted in at least 18 species of fish at Woods Hole, in 22 at Beaufort, and in 2 in Bermuda. The intermediate hosts of this parasite include a great range of species. They are not even confined to the teleosts, but include some of the sharks and skates as well. The occurrence of encysted cestodes in sharks and skates is not as rare as it was thought to be by Beneden, who coined the word xenosite, or stranger, for such cases.

It does not come within the plan of this paper to give details of distribution. The following typical examples, therefore, will probably be sufficient to illustrate this matter of the limitation in the number of final hosts and the wide range of intermediate hosts.

DISTRIBUTION OF TYPICAL CESTODES IN FINAL AND INTERMEDIATE HOSTS.

Cestode.	Usual or only known final host.	Intermediate host.
Tetrarhynchus bisulcatus	Carcharhinus obscurus	18 species of Woods Hole fishes. 22 species of Beaufort fishes. 2 species of Bermuda fishes.
Rhynchobothrium bulbifer	Mustelus canis	22 species of Woods Hole fishes.
Rhynchobothrium speciosum	Carcharhinus obscurus	12 species of Woods Hole fishes. 3 species of Beaufort fishes. 5 species of Bermuda fishes. 4 species of Tortugas fishes.
Rhynchobothrium imparispine	Raja ocellata	28 species of Woods Hole fishes.
Otobothrium crenacolle	Sphyrna zygæna	In a large number of Woods Hole and Beaufort fishes, and in 3 Bermuda fishes; especially abundant in flesh of butterfish.

In view of the frequency of occurrence of cestode parasites in body cavities of marine fishes their comparative rarity as flesh parasites is striking. While larval cestodes have been found in the great majority of the species of fish I have examined, in those cases where a considerable number of individuals were examined the number of species of fish in which I have found parasites in the flesh is surprisingly small. A glance at the appended tables will show the small number of fishes found to harbor parasites in the flesh among those examined in the summer of 1908. When it is remembered that with no more than three exceptions entozoan parasites have been collected from all the species of fish named in the tables, that flesh parasites are recorded from only 12 species out of a total of 76, and that in only 2 of the 12 species were flesh parasites found in many individual fish or in large numbers in any, the comparative scarcity of flesh parasites in the marine fishes becomes a still more noteworthy fact.

Aside from the butterfishes, which will be considered later, the only instances in which I have found cestodes in the flesh of marine fishes under conditions which led me to regard their occurrence as other than accidental are the following:

1. Two species of gars, *Tylosurus acus* in Bermuda and *T. rapidoma* at Beaufort. Two fish of the former species and one of the latter were examined. In each of them there were many cestodes in the flesh. This cestode was described[a] under the name *Otobothrium* sp. The examples from the Bermuda gars proved to be the same species and have been given a specific name, *O. penetrans.*[b]

2. The sand launce (*Ammodytes americanus*). I have found a species of cestode (*Rhynchobothrium bulbifer*) in the flesh of a considerable number of these fishes in previous years, although none were found in the lot which was examined this season.

3. Two sticklebacks (*Gasterosteus bispinosus*) which were examined this season had each many cestodes encysted in the flesh.

Two of the three cases cited above are based on too small a number of individuals to be of much value, at the same time the manner of infection in each case was such as to lead me to more than suspect that they are common carriers of cestode parasites in the flesh.

THE CASE OF THE BUTTERFISH.

A reference to the appended table III, wherein details of the examination of the butterfish are given, and to tables I and II, where a summary is given in which the parasitism of the butterfish may be compared with that of other food fishes examined during the summer of 1908, will show that in respect to the matter of flesh parasites the butterfish occupies a unique position. All the other food fish, as a rule, show either none or only an occasional individual with parasites in the flesh, and even in cases where any were found in the flesh, there were at most few, often but one. The butterfish, on the other hand, proves to be so generally infected that the infected condition really seems to be the normal. An examination in the season of 1908 of 720 butterfish, ranging in length from 6 to 23 centimeters, resulted in finding cestode cysts in the flesh of all but 21.

As this case of parasitism has already been reported it is not necessary to devote much time to it here.[c] Inasmuch as the case is a most remarkable and exceptional one, however, there are certain phases of the subject which should be considered.

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[a] Linton, E.: Parasites of fishes of Beaufort, N. C. Bulletin, Bureau of Fisheries, vol. XXIV, 1904, p. 357.

[b] Linton, E.: Notes on parasites of Bermuda fishes. Proceedings U. S. National Museum, vol. XXXIII, 1908, p. 100

[c] Linton E.: A cestode parasite in the flesh of the butterfish. Bulletin Bureau of Fisheries, vol. XXVI, p. 1–48, pl. 1 and 2.

This parasite is a cestode, described first from adult forms found in the spiral valve of the hammerhead shark (*Sphyrna zygæna*).[a] In the butterfish it is found, sometimes in enormous numbers, in the flesh. The favorite resting place of these cysts is between the vertebral spines on the ventral side of the backbone, but they are often almost equally abundant between the vertebral spines on the dorsal side of the backbone, and scattered generally through the muscles of the body, for the most part in a dorsoventral median plane. The cysts are small, usually 1 millimeter or less in greatest diameter, oval in shape, and present the appearance of small fish-roe. In the young fish they are translucent white, which becomes tinged with yellow in the larger fish. Each cyst, when crushed, liberates a characteristic cestode nurse (plerocercus or blastocyst) in which is the scolex or head of the tapeworm. In all the cysts that I have studied this season, even those from the smallest fish, I have not failed to find a well-formed scolex bearing the characteristic marks by which the species may be recognized. In former years the smaller fish were found to be much less infected than the older fish and many were found in which no cysts were seen. Also in former years cysts were found in some of the smaller fish which contained scoleces in which the characteristic hooks on the proboscides and the pits on the bothria were not yet developed. In the season of 1908 even the smaller fishes were found to be largely infected. As they are recorded in the tables, the grouping into "cysts in enormous numbers," "very numerous," "numerous," etc., is more or less arbitrary. It is to be hoped, however, that it will convey a fairly correct picture of the actual condition. Of course the terms are to be understood as of only relative significance. A small fish, for example, recorded as having numerous cysts would contain a smaller actual number than would a large fish similarly characterized.

This case of parasitism of the individuals of a species which inhabits the open sea is most exceptional. In a confined area, as in a small lake, or in exceptional conditions, such as obtain in as large a body of water as Yellowstone Lake, a general prevalence of parasites can be accounted for.[b] But why should the butterfish and its near relative, the harvestfish, be so excessively and universally parasitized while other species of fish, though they inhabit the same waters and feed on practically the same food, escape? That an occasional butterfish should be found with these cysts in the flesh would not of itself be a thing remarkable. That these cysts should even be present in very large numbers, even thousands, as is often the case, is not inexplicable. That such an enormous percentage should be affected, as is proved by the facts exhibited in the tabular statements in this paper, is the really difficult matter to explain.

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[a] Linton, E.: Notes on entozoa of marine fishes of New England, with descriptions of several new species. Report U. S. Fish Commission, 1887, p. 850–853, pl. XIII, fig. 9–15; pl. XIV, fig. 1–4. 1891.

[b] Linton, E.: On two species of larval Dibothria from the Yellowstone National Park. Bulletin U. S. Fish Commission, vol. IX, p. 65–79, pl. XXIII–XXV; p. 337–358, pl. CXVII–CXIX. 1891.

1. As to the fact that these parasites have the habit of gaining lodgment in the flesh of the butterfish, it may be said that evidently here is a case of mutually favoring conditions. A careful study of the anatomy of the butterfish, especially of the vascular system, may throw some light on the problem. At any rate the fact that the larvæ of *Otobothrium crenacolle* penetrate to the muscles of the butterfish and harvestfish, instead of lodging in the submucous coat of the stomach and intestine, as is their habit in other fishes in which this cestode has been found, is probably a purely physiological question. The other species of *Otobothrium* mentioned above presents a somewhat similar case. In the case of the gars, however, a large number of small gars have been examined for flesh parasites without any being found. Either the infected gars were exceptional cases, or it is only in certain regions that the conditions favor the ingestion of cestode eggs.

It would appear that certain species of the Tetrarhynchidæ, and notably of the genus *Otobothrium*, are enabled to penetrate to the muscles of certain intermediate hosts, possibly on account of being of suitable size and structure so that they are carried by the blood away from the immediate vicinity of the viscera. Or, more probably, there is here a case of accidentally mutual adjustment on the part of the anatomical structure, and possibly the physiological habit of the butterfish on the one part, to the structural features, and possibly the physiological requirements of the parasite on the other.

2. That these cysts should be present in very large numbers in a single fish is not difficult to understand once given the possibility of their being in the flesh at all. A free, ripe segment of the cestode *Otobothrium crenacolle* will remain living for hours after it has been placed in sea water. Moreover, it may contain an enormous number of eggs. There is no necessity, therefore, in postulating some method of reproduction of cysts by budding, for which there is not the slightest evidence, to account for the presence of a large number of cysts in a single butterfish. The ingestion of a single joint, in which there is a large number of eggs, will be sufficient to give rise to several hundred, possibly a few thousands of cysts, each with its living scolex. Indeed it is rather easier to explain the cases in which there are hundreds of cysts than it is to explain those in which there are less than a dozen. Cases of slight infection are probably due to the accidental swallowing of a few eggs instead of an entire joint. This might happen if a fish swallowed a bit of fecal matter which might well have one or more eggs intermingled with it.

3. How is the apparently almost universal parasitism of the butterfish to be explained? Before attempting to answer this question it may be well to consider whether the case, aside from the fact that the cysts are in the muscles, is unique. Unfortunately, I have not my notes arranged in such a way as

will enable me to tabulate readily or completely the data which it is desirable to marshal for this particular purpose. The following statements, however, are abundantly warranted from many observations made during previous years, and have some bearing on the immediate question.

The stomach wall of most squeteagues (*Cynoscion regalis*) contains a greater or less number of cysts of a definite species of cestode (*Tetrarhynchus bisulcatus*) which is found in the adult stage in the stomach and intestine of the dusky shark. Furthermore there is found in the cystic duct of the same fish a larval cestode (*Scolex polymorphus*), almost always in considerable number. The same parasite is also quite common in the cystic duct of the summer flounder (*Paralichthys dentatus*). For example, during the past summer I examined a flounder from Menemsha Bight which appeared to be suffering from a case of jaundice. The whole surface was yellow, the unpigmented under side being a decidedly bright lemon yellow. The flesh and the viscera were also yellow. The cystic duct was occluded by a mass which looked something like a soft tumor. When this mass was cut open it was found to consist of a cluster of these cestodes. Their heads were buried in the mucous membrane while their bodies effectually stopped the lumen of the duct. Other cases of prevalent parasitism in intermediate hosts could be cited.

In like manner cases of prevalent parasitism of final hosts are not lacking. Thus every specimen of tiger shark (*Galeocerdo tigrinus*) which I have examined, about 15 in all, at intervals during many years, has been found to harbor large numbers of a singular cestode (*Thysanocephalum crispum*), a species which has not been found as yet in any other host. Again, nearly every sand shark in the Woods Hole region harbors a species of cestode (*Crossobothrium laciniatum*), often in large numbers.

Plainly, then, all that is necessary to make parasitism, by means of a given species of parasite, affect the majority of the individuals of the host, is to have the source of infection sufficiently widespread, abundant, and pervading in the natural habitat of the infected species. Not only must the final and the intermediate hosts, in the case of the cestodes, be related to each other as eater and eaten, but their association together must be otherwise close, else the intermediate host will not become largely infected. At present I can see no other explanation of the almost universal prevalence of this parasite in the flesh of the butterfish than that which I gave in the paper cited above. The butterfish must have formed the habit of following sharks, attracted by the bits of food which float off in the water while the shark is feeding. The voracious, fish-eating sharks tear and shake their prey as they eat it, so that there must often be in the vicinity of a shark a cloud of bits and shreds of meat which are greedily sought by smaller fish. This zone of sure, even if it be intermittent, food supply

can not fail to be attractive to small fish. These small fish, especially when traveling in schools, must themselves often pay tribute to the shark. There is thus established by the common bond of mutual advantage an association which must be extremely favorable to the parasite which can thrive well in both the intermediate and the final host which are the principals in this association. From time to time the ripe joints of the cestode will be discharged into the water along with the fæces from the intestine of the shark. These joints look, behave, and doubtless feel to a small fish much as other small swimming forms, entomostracans, annelids, and the like do, and consequently are picked up by them. In some such manner do the eggs of the cestode gain lodgment in the intermediate host. What is difficult to picture is the actual situation which not only makes possible but actually brings to pass the infection of practically all the butterfish. A study of the appended tables will make it quite clear that among the half grown and fully grown butterfish an individual which is free from these cysts in the flesh is exceptional.

Butterfish are not fish of rare occurrence traveling singly or even in very small schools. They are taken in considerable numbers in the fish pounds, and evidently move in fairly large schools. How far they migrate along the coast is not known. I have found the adult cestode, though not abundant, in the sharp-nosed shark at Beaufort. This shark is abundant. The other known final host is the hammerhead shark, which is not an abundant species, though it is one which has a wide distribution. I hope to be able to gather more data on this interesting problem of distribution.

GENERAL CONSIDERATIONS AS TO FLESH PARASITES OF FISHES.

To what extent is the food value of fishes impaired by the presence of parasites in the flesh?

With the exception of the common butterfish (*Poronotus triacanthus*), and its rarer relative the harvestfish (*Peprilus alepidotus*), I find that the marine food fish I have thus far examined are so free from parasites in the flesh that the question has, at present, little more than an academic or rather a purely zoological interest. To take the case of the butterfish, it may be remarked:

1. Since the cysts might be easily mistaken for ova by one whose knowledge of the natural position of the ovary is indefinite, and since the nutritive value of the cysts is doubtless little different from that of so much fish-roe, it is likely that the food value of the parasitized fish is not much different from that of the nonparasitized or but slightly parasitized fish of the same weight. There is no evidence of any inflammatory or pathological condition of the tissues of the fish brought about by the presence of the cysts. From another point of view the cysts are a decided detriment. A number of badly parasitized fish was selected

and an equal number, corresponding in length and depth, of nonparasitized, or but slightly parasitized fish. The two sets were weighed and the weights compared. This was repeated a number of times. In each instance the parasitized fish weighed less than the others.

2. It can be quite confidently asserted, although no feeding experiments have been attempted, that these cysts, even if they were to be swallowed uncooked, would fail to develop in man, or indeed in any warm-blooded animal. Even among fishes they are restricted to a few closely related sharks for their final hosts.

3. The greatest impairment which is wrought on the value of the butterfish as food by this parasite is the subjective effect which the knowledge of its presence in the flesh of the fish has on the mind or imagination of the consumer. This is probably in large part due to the fact that the parasite is a parasite, and especially a worm parasite. The conjunction of such appetite-destroying ideas as are embraced in the mere words worm and parasite is bad enough, but when one substitutes the word cestode for worm, and then is obliged to confess that the word cestode means tapeworm the situation is not made better in the least.

Touching the matter of the discovery of this parasite in the flesh of the butterfish, I may be permitted to say that I am very sorry to be the bearer of this painful news. Possibly some compensation will be afforded by the further intelligence which I feel warranted in bringing that the plight of the butterfish is a most exceptional one, and that so far as my investigations have gone, it can be stated with entire confidence that the flesh of the marine food fishes is, to a very high degree, free from parasites. Certainly the examination of such excellent food fishes as the scup, bonito, squeteague, flounders, etc., as shown in the appended tables, is sufficient to warrant the conclusion that so far at least as the investigation has progressed, the presence of parasites in the flesh of our marine food fish, excepting always from this guaranty the butterfish, is very exceptional.

TABLE I.—SHOWING SUMMARY OF RESULTS OF THE EXAMINATION OF FOOD FISHES FOR PARASITES IN THE FLESH, WOODS HOLE, MASS., JULY TO SEPTEMBER, 1908.

Name of fish.	Number of fish examined.	Parasites found in the flesh.	Name of fish.	Number of fish examined.	Parasites found in the flesh.
Eel (Anguilla chrysipa)	4	None.	Butterfish (Poronotus triacanthus).	720	Cysts in 699; large numbers in most cases.
Round herring (Etrumeus sadina).	243	None.	White perch (Morone americana)	2	None.
Herring (Clupea harengus).	1	Sporozoa.	Scup (Stenotomus chrysops).	73	None.
Alewife (Pomolobus pseudoharengus).	73	Sporozoa in 21.	Squeteague (Cynoscion regalis).	39	Four cysts in 3 fish.
Glut herring (Pomolobus aestivalis).	1	None.	Kingfish (Menticirrhus saxatilis).	19	None.
Smelt (Osmerus mordax)	21	None.	Cunner (Tautogolabrus adspersus).	59	None.
Silverside (Menidia notata).	28	One cyst.	Tautog (Tautoga onitis)	37	None.
Mullet (Mugil cephalus)	23	None.	Triggerfish (Balistes carolinensis).	2	None.
Barracuda (Sphyræna borealis).	5	None.	Whiting (Merluccius bilinearis).	24	None.
Mackerel (Scomber scombrus).	2	None.	Pollock (Pollachius virens).	3	None.
Chub mackerel (Scomber colias).	10	One cyst.	Tomcod (Microgadus tomcod).	5	None.
Bonito (Sarda sarda)	57	None.	Hake (Phycis tenuis)	4	None.
Pilotfish (Seriola zonata).	4	None.	Hake (Phycis chuss)	5	None.
Mackerel scad (Decapterus macarellus).	9	None.	Summer flounder (Paralichthys dentatus).	9	None.
Yellow crevalle (Caranx chrysos).	1	None.	Sand dab (Lophopsetta maculata).	16	None.
Round pompano (Trachinotus falcatus).	5	None.	Winter flounder (Pseudopleuronectes americanus).	40	One cyst.
Bluefish (Pomatomus saltatrix).	58	None.			
Harvestfish (Peprilus alepidotus).	12	Numerous cysts in all.			

TABLE II.—SHOWING SUMMARIZED RESULTS OF EXAMINATION OF FISHES FOR PARASITES IN THE FLESH, DRY TORTUGAS, FLA., JUNE TO JULY, 1908.

Name of fish.	Number of fish examined.	Parasites found in the flesh.	Name of fish.	Number of fish examined.	Parasites found in the flesh.
Green moray (Lycodontis funebris).	1	None.	Bermuda chub (Kyphosus sectatrix).	2	None.
Great barracuda (Sphyræna barracuda).	3	None.	Cock-eye pilot (Eupomacentrus leucostictus).	3	None.
Blue runner (Caranx ruber).	4	None.	Cow pilot (Abudefduf saxatilis).	6	None.
Red grouper (Epinephelus morio).	5	None.	Chlorichthys bifasciatus	1	None.
Rockfish (Mycteroperca venenosa).	4	A few degenerate cysts in flesh of one and under the peritoneum of another.	Blue parrotfish (Scarus cœruleus).	6	None.
			Parrotfish (Scarus croicensis).	5	None.
			Scarus sp.	2	None.
Big eye (Priacanthus cruentatus).	1	None.	Black angelfish (Pomacanthus arcuatus).	10	None.
Gray snapper (Neomænis griseus).	14	None.	Angelfish (Angelichthys isabelita).	2	None.
Schoolmaster (Neomænis apodus).	1	None.	Blue tang (Teuthis cœruleus).	8	None.
Muttonfish (Neomænis analis).	1	None.	Surgeonfish (Teuthis hepatus).	12	None.
Yellowtail (Ocyurus chrysurus).	11	None.	Shellfish (Lactophrys triqueter).	1	None.
Yellow grunt (Hæmulon sciurus).	3	None.	Shellfish (Lactophrys trigonus).	4	None.
White grunt (Hæmulon plumieri).	54	None.	Cowfish (Lactophrys tricornis).	2	None.
Porgy (Calamus calamus)	12	Two cysts in one, one cyst in another.	Shark sucker (Echeneis naucrates).	2	None.

TABLE III.—SHOWING OCCURRENCE OF CESTODE CYSTS IN FLESH OF BUTTERFISH, AND RELATION TO SIZE OF HOST.

Length in centimeters.	Number of fish examined.	Number of fish with—				
		Very numerous cysts in flesh.	Numerous cysts in flesh.	Many cysts in flesh.	Few cysts in flesh.	No cysts in flesh.
1904.						
20 centimeters and over	100	21	63	5	11	0
15 to 20 centimeters	42	8	7	13	13	1
10 to 15 centimeters	56	4	4	19	25	4
Less than 10 centimeters	4	0	0	0	1	3
Total for 1904	202	33	74	37	50	8
1905.						
20 centimeters and over	242	69	54	32	80	7
15 to 20 centimeters	75	21	5	11	26	12
10 to 15 centimeters	26	2	1	1	8	14
Less than 10 centimeters	4	0	0	0	0	4
Total for 1905	347	92	60	44	114	37
1906.						
20 centimeters and over	32	17	6	3	5	1
15 to 20 centimeters	24	7	1	4	7	5
10 to 15 centimeters	7	0	0	0	0	7
Total for 1906	63	24	7	7	12	13
1907.						
20 centimeters and over	12	1	2	4	4	1
1908.						
20 centimeters and over	180	75	38	38	26	3
15 to 20 centimeters	129	61	32	22	14	0
10 to 15 centimeters	207	63	67	42	29	6
Less than 10 centimeters	204	3	30	75	84	12
Total for 1908	720	202	167	177	153	21
Total for 1904–1908	1,344	352	310	269	333	80

STRUCTURE AND FUNCTIONS OF THE EAR OF THE SQUETEAGUE

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INTRODUCTION.

Although fishes have no external ears, they have long been known to possess internal ears which in complexity of structure often approach even those of the higher vertebrates. It is therefore natural to expect that the functions ascribed to the internal ears of birds, mammals, etc., would be found in one form or another among the fishes. These functions are chiefly three—first, hearing, which is historically the earliest function to be ascribed to the internal ear; second, an influence on bodily equilibrium both when the body is at rest and when it is in motion, a view founded upon the experimental investigations of Flourens (1828); and, third, an influence on tonus or strength of contraction of the skeletal muscles, as demonstrated first by Ewald (1892).

The ear of the squeteague (*Cynoscion regalis*) is a well-developed organ and shows in a striking way all the essential parts of the ears in fishes. The male squeteague, moreover, is well known to produce sounds through a special mechanism not possessed by the female (Tower, 1908). Because of these structural conditions and of the highly specialized habit of sound production in these fishes, I was led to make an investigation of their ears. The only objection to this species for such study is its lack of vitality. It can not be kept many days in confinement, even in large fish boxes in the open sea, and it is not resistant to the effects of operations. Nevertheless, the exceptionally favorable conditions at the Woods Hole Laboratory of the Bureau of Fisheries made it possible to overcome these obstacles sufficiently to carry out the proposed work.

ANATOMY OF THE EAR.

The internal ears of the squeteague are relatively large organs and are lodged in the lateral walls of the posterior part of the skull. In a dry preparation of the skull their position is indicated on the ventral side by two smooth elongated bony capsules (fig. 4, pl. CXXII), whose posterior ends lie close together near

the occipital condyle and whose anterior ends diverge as they approximate the regions of the orbits. These capsules form a part of the bony roof of the mouth and are separated from this cavity by only a thin covering of mucous membrane. In an adult fish the capsules are nearly an inch and a half (3.5 cm.) in length and their longitudinal axes diverge from each other anteriorly at an angle of a little over 40°. The internal ears lie partly in these capsules and partly in the bony wall of the skull dorsal to the capsule (fig. 2). Each ear consists of a sacculus with its appended lagena, and a utriculus and its semicircular canals.

The sacculus is an elongated, thin-walled structure which lies in the cavity of the bony capsule. It has the shape of a long flattened bean, and measures in an adult fish a little over 1¼ inches (3.5 cm.) in length by almost ½ inch (1.1 cm.) in width. The walls of the sacculus are very thin and conform closely to the shape of the inner surface of the bony capsule, to which they seem to be molded. Much of the median wall of the sacculus is occupied by a large sensory patch, the macula acustica sacculi, which receives the most considerable branch of the eighth nerve. This patch is in the form of an elongated band of moderate width extending lengthwise of the sacculus; its anterior end spreads out into a very considerable oval area; its posterior end is marked by a smaller expansion. The lateral wall of the sacculus is smooth and without special nerve terminals.

Each sacculus contains a large ear stone or otolith, the sagitta (1, 2, 3, pl. CXXII), to use the term employed by Webb (1905), which almost completely fills its cavity. In full-grown squeteagues these otoliths are conspicuous structures; they may measure 1¼ inches (3.2 cm.) in length by ⅜ inch (1 cm.) in width. Their dry weight may exceed 25 grains (1.7 gm.). They are white and hard and, excepting for a small organic residue, dissolve completely with effervescence in dilute acetic acid. They are chiefly carbonate of lime, and their specific gravity, 2.84, is between those of the minerals calcite and aragonite. Their concentric structure favors the belief that they are secretions from the sacculus. Their lateral faces are irregularly concave (fig. 1, C–F, pl. CXXII) with a dorsal blade-like edge and a ventral blunt one. Posteriorly they are roughly pointed; anteriorly they are flattened out into an almost spatula-like ending. Their median faces (fig. 1, A–B) are relatively smooth with a slightly depressed figure on them corresponding to the form of the macula acustica sacculi, against which they are well adapted for resting lightly.

At the posterior end of the sacculus is a small triangular pocket, the lagena, which contains a flattened otolith, the asteriscus, and a single sensory patch, the papilla acustica lagenæ, to which a branch of the eighth nerve is distributed.

Although the sacculus communicates freely with the lagena, it does not connect with the utriculus. A careful search in fresh and in well-preserved material for a communication between these two parts failed to reveal the least

trace of such a structure. This condition has been reported already by Retzius (1881, p. 215) for 20 of the 33 species of teleosts that he studied. Among these there were 15 that belonged to the same order as the squeteague, the Acanthopteri, and in only 1 of these 15, *Gasterosteus*, was the sacculus found to communicate with the utriculus. In this respect, then, the squeteague is like the great majority of the acanthopterous fishes thus far examined.

The utriculus is a slender sac which lies dorsal to the sacculus and is of about half the length of that structure. From near its middle a large duct, the sinus superior, extends dorsally, and from the upper end of this sinus pass off the anterior and the posterior semicircular canals. Each canal bends ventrally and after enlarging into an ampulla, connects with an end of the utriculus. Close to the region at which the ampulla of the posterior canal unites with the utriculus, the horizontal canal arises and, after a semicircular course, it enlarges to form an ampulla and then unites with the utriculus near the place where the ampulla of the anterior canal joins that organ. In the utriculus close to its anterior end is a sensory patch, the macula acustica recessus utriculi, over which a small otolith, the lapillus, is found. Each of the three ampullæ of the semicircular canals contains a sensory patch, the crista acustica, but these are unprovided with otoliths. No macula neglecta could be found. Unlike the sacculus and the lagena, which are mostly surrounded by bone, the utriculus and the semicircular canals lie for the most part in the loose tissue between the brain and the wall of the skull. The horizontal canal and the posterior vertical canal are in part surrounded by bone, but the anterior vertical canal merely rests against the bone that forms the inner surface of the skull.

It is thus clear that the ear of the squeteague is not a single sense organ, but two organs structurally distinct—what may be called the saccular organ including the sacculus with its outgrowth, the lagena, and its two sensory patches and two otoliths, and the utricular organ including the utriculus and its three semicircular canals, with four sensory patches and one otolith.

FUNCTIONS OF THE EAR.

As was stated at the outset, three chief functions have been ascribed to the vertebrate ear. The sense of hearing has long been associated with the cochlea and adjacent parts of the internal ear, and recent discoveries confirm this view. The bodily equilibrium of vertebrates was shown by Flourens (1828) to be seriously interfered with on cutting the semicircular canals, and though there has been opposition to this view, the work of Mach (1874a, 1874b), Breuer (1874), and many recent investigators has added much in support of it. Finally, Ewald (1892) has pointed out, in a most elaborate study, that the internal ear exerts an influence on the tonus of skeletal muscles—i. e., the vigor of an animal's movements is largely dependent upon the integrity of this sense organ.

Since the ear of the squeteague is really double, in that the saccular and utricular organs are anatomically separate, and since these organs are large and fairly accessible, it seemed reasonable to expect that experiments upon them might be devised which would lead to a more definite knowledge as to the localization of function in these parts.

UTRICULAR ORGAN.

After some practice on the heads of dead squeteagues it was found possible to destroy the utriculus and semicircular canals of live fishes by cutting them with a long, narrow knife blade inserted through a small incision on each side of the head, and yet to leave the sacculus and its appended parts uninjured. This operation could be performed without serious bleeding and without injury to the brain. The slight opening thus made through the skin and subcutaneous parts closed of itself, and even after the death of the fish it showed no tendency to gap open. It was expected that these operations would be followed by a loss of equilibrium, but it was soon clear that the squeteague could still keep its upright position. Since this fish, like many others, is in unstable equilibrium (Monoyer, 1866) when in its so-called resting posture, I suspected that the retention of its upright position after the loss of the utricular organ was dependent upon the eyes, and to eliminate the action of these sense organs a set of blinders was devised. These were attached to the head of the squeteague by means of a cord harness. A single loop of cord was tied snugly round the body of the fish just posterior to the pelvic fins, and from the point at which this loop crossed the dorsal line a cord was run over the median dorsal line of the head to the large premaxillary teeth, where it was made fast. To this median dorsal cord were attached two cloth flaps that could be turned down over the eyes and held there by a cord, passed from one flap to the other under the jaws. In this way the eyes could be covered without interfering with the freedom of movement of the mouth and gills, for unless these parts are entirely free the animal is extremely restive and may even lose its balance.

Five sets of four fishes each were tested for the effects of destroying the utriculus and the semicircular canals. Before operating upon the fishes each was tried to see that it responded to sound vibrations and that it swam normally with the eyes covered. In testing the reactions to sound, the fish was placed in a large wooden tank of sea water, and after it had become quiet the side of the tank was tapped once or twice with a mallet in such a way that the fish could not see the movements. At each tap the fish almost invariably made a slight spring forward. To test the relation of the eyes to equilibrium, the harness was put on the fish and the eyes covered by the blinders. The majority of fishes immediately swam away slowly, though in normal equilibrium, but a few

lost orientation and would even rest on their sides on the bottom of the aquarium. In only such fishes as responded to the tapping and swam upright after the blinders had been put on them were the utriculus and the semicircular canals destroyed. The following records from one of the five sets of fishes tested will give a fair idea of the results of these experiments:

Fish No. 1 was operated upon for the destruction of the right and left utriculi and the semicircular canals. After the operation the fish swam irregularly, often revolving on its long axis. It died about three hours after the operation. Dissection showed extensive hemorrhages within the cranium.

Fish No. 2 was subjected to the same operation as No. 1. After the operation the fish swam irregularly for about half an hour. It then reassumed normal equilibrium both in resting and in swimming. Five hours after the operation it still swam normally. The blinders were then put on it and it lost equilibrium and swam in irregular spirals, but it regained its equilibrium as soon as the blinders were removed. This test was repeated several times during the next few hours and always with the same results. During this period the fish was also placed several times in the wooden aquarium; it always responded normally to the taps of the mallet on the aquarium wall. At all times after the operation the locomotor movements of the fish were weaker than they had been before the utriculus was destroyed, a condition that made it much easier to catch the fish in a hand net after the operation than before it. The fish retained its power of orientation till about the time of its death, thirty-two hours after the operation. On dissection the utriculi and semicircular canals were found to be cut through in many places, but the sacculi and brain were intact.

Fish No. 3 was subjected to the same operation as No. 1. The fish swam irregularly and rested in unusual positions; it never regained its equilibrium. It died in about twenty hours after the operation. A post-mortem examination showed that the medulla had been partly cut.

Fish No. 4 was subjected to the same operation as No. 1. The fish at first swam irregularly, but twenty minutes after the operation it had regained its equilibrium. In its response to tapping, its method of swimming when blinded, and in its muscular weakness it resembled No. 2. It lived for about two days after the operation. On examination, its utriculi and semicircular canals were found much cut to pieces, but the sacculi and brain had not been injured.

Of the total of twenty fishes in which the utriculi and semicircular canals had been destroyed, 11 through early death or other unfavorable conditions proved to be useless for experimentation. The remaining 9 reacted much the same as No. 2 and No. 4 in the set just described. In all 9, so far as I could judge, the animals were as sensitive after the operation as before it to the noise produced by tapping on the side of the aquarium. Immediately after the operation all swam with disturbed equilibrium, but within an hour, and often in even less time,

they reassumed their equilibrium. This was persistently retained up to about the time of death, except when their eyes were temporarily covered. With the blinders on, they invariably swam irregularly. All 9 fishes after the operation were noticeably weaker in their responses than before it. Most of these fishes lived only a few days and only one lived for as long as five days after the operation.

These observations show that the utriculus and the semicircular canals of the squeteague are not essential for the responses of these animals to sounds. They show also that though these organs are concerned with equilibrium, they share this function with the eye, for it is only after both sets of sense organs have been rendered ineffective that permanent disturbances in equilibrium occur.

There is, however, no reason to assume that in this relation the utriculus and its canals stand second to the eye. They are certainly of prime importance as sense organs in which impulses originate for the reflexes of equilibrium. In this respect my results fully confirm those of Loeb (1891a, 1891b), Ewald (1891, 1907), Kreidl (1892), Lee (1892, 1893, 1894, 1898), Bethe (1894, 1899), Gaglio (1902), Quix (1903), and Fröhlich (1904b) on various fishes. They also agree with those of Tomaszewicz (1877), Kiesselbach (1882), Sewell (1884), and Steiner (1886, 1888) in that they make evident that the destruction of the utriculus and the semicircular canals is not necessarily followed by permanent disturbances in equilibrium. Had these investigators, however, taken steps to eliminate the influence of the eyes of the fishes on which they worked, it is probable that they would have found these animals incapable of retaining their equilibrium. I therefore can not agree with their conclusion, briefly put by Ayers (1892), that the ear has nothing to do with equilibrium. The utriculus and the semicircular canals of the squeteague are one or both certainly concerned with this function, and this conclusion probably holds good for other fishes, but whether the sense organs involved are the cristæ acusticæ of the semcircular canals or the macula acustica recessus utriculi with its otolith, or both, I can not say. These parts are also concerned with muscular tonus, as is seen by the weakness of the fish after their destruction, a condition already observed by Ewald (1891, p. 5; 1907, p. 191) for *Anguilla* and by Bethe (1894, p. 575) for *Perca* and *Sardinius*.

SACCULAR ORGAN.

The sacculus and lagena each contain sensory patches, i. e., on the median face of the sacculus is the very large macula acustica sacculi, and on the corresponding side of the lagena the much smaller papilla acustica lagenæ. The sacculus, as already mentioned, contains a very large otolith, the sagitta, which rests on the macula acustica sacculi, and the lagena contains a much smaller one, the asteriscus, which covers the papilla acustica lagenæ. For

experimental purposes the sacculus is scarcely accessible from the dorsal or lateral aspects of the head, but it is so near the roof of the mouth that I determined to approach it from that side. As already stated, it is separated from the mouth by only a thin layer of bone and mucous membrane. It was not difficult to hold the mouth of a squeteague open and, by means of long bone forceps, to cut through this thin wall and thus gain access to the sacculus, but this operation was attended with so much loss of blood that it was finally abandoned.

Since the lateral wall of the sacculus is essentially nonnervous, it occurred to me that I might force the sagitta off the sensory patch on which it rested and against the nonnervous lateral wall by driving a pin in an appropriate direction through the thin roof of the mouth. A little practice on the heads of dead fishes showed that this could be accomplished with comparative ease. The pins used were long steel hat pins about 8 inches (20 cm.) in length. These could be easily manipulated in the open mouth of the fish, and after they had been forced into place against the sagittæ they could be cut off short next the roof of the mouth. Apparently they offered no obstacle to the breathing and other mouth movements of the fish. Squeteagues that had thus been operated upon lived about as long as normal squeteagues do in confinement. Of 10 fishes in which it was attempted to pin off the otoliths in this manner, 7 survived for nearly a week and were used in the following experiments. The 3 others died during the experiments, and hence their records were omitted as incomplete. In all 10 cases, final dissection showed that the otoliths had been pinned against the nonnervous side of the sacculus as was intended. The tests carried out on the 7 vigorous fishes gave very uniform results.

Before the otoliths were pinned down, each squeteague was tested with the blinders for equilibrium and in the wooden aquarium for responses to sound. After pinning down the otoliths the fishes swam at first irregularly, but in ten minutes at most they regained their equilibrium, and they retained this even when the blinders were put on them. After the immediate effects of the operation of pinning down the otoliths had disappeared, the equilibrium of these fishes was indistinguishable from that of normal fishes. The vigor of their movements was likewise unimpaired by this operation. After it they were about as difficult to catch with a hand net as before it. On testing them with sound stimuli they were found to be only slightly responsive as compared with their former condition. Thus a fish that before the pinning of the sagittæ had responded to every tap of the mallet on the wooden wall of the aquarium, reacted to only 3 in 30 taps after the sagittæ were anchored laterally. This considerable reduction in reactiveness was also noticed in the other 6 fishes. When, moreover, a squeteague with the otoliths pinned down was placed in the aquarium with a normal fish and the wall of the aquarium was tapped, it was quite easy to determine from the movements of the 2 fishes which was the

normal one, for the normal fish almost invariably responded by a slight leap forward to every tap, while the other fish only very rarely reacted. The same was true when normal *Fundulus heteroclitus* were put in the aquarium and compared with squeteagues whose ear-stones had been pinned. I therefore believe that the larger otolith of the sacculus, the sagitta, is concerned with the squeteague's sensitiveness to sound, and further, for reasons already given, that it has nothing to do with equilibrium or with muscle tonus.

These conclusions are in accord with the observations of several other investigators. Thus, so far as hearing is concerned, Smith (1905) has pointed out that in all sciænid fishes which drum, as the squeteague does, the sagittæ are very large, but in *Menticirrhus*, which does not drum, these otoliths are relatively small. Hence, the size of the otolith seems to be related to the drumming habit, as might be expected if the otoliths are concerned with hearing. Further, Piper (1906a) has demonstrated that a negative variation is observable in the eighth nerve of *Esox* when that portion of the ear of *Esox* which contains the otoliths is subjected to sound vibrations. From the standpoint of equilibrium Laudenbach (1899) has already shown that the removal of the otoliths from the ears of *Siredon* and the frog has no effect on the subsequent success of these animals in keeping themselves upright, a state of affairs in agreement with my experience in pinning down the otoliths in the squeteague. These observations therefore confirm me in the belief that the sagitta of the fish's ear is in some essential way concerned with the responses of these animals to sounds, as surmised by Scott (1906), and has nothing to do with equilibrium or muscle tonus. So far as equilibrium is concerned this conclusion is rather the reverse of what would be anticipated, for in the invertebrates, at least, the otoliths have been clearly shown to be concerned with equilibrium, and this function has been definitely ascribed by Breuer (1891), Sherrington (1906), and others to these bodies in the vertebrates; but this opinion is not supported by my observations.

The sagittæ in the ears of vertebrates are certainly not merely tolerated foreign bodies, as Ayers (1892, p. 309) has maintained, but, as has just been pointed out, they are of real functional significance. How they act in the reception of sound is not known with certainty; but since in the squeteague they have a specific gravity of 2.84 and that of the whole head is about 1.8, it is quite probable that when sound vibrations influence the normal fish they induce the relatively lighter parts of the head, including the macula acustica sacculi, to vibrate against the relatively heavier otolith; in other words, the otolith is a relatively stable body against which the auditory hairs of the macula acustica sacculi may strike. In my opinion sound stimulates the auditory hairs in some such mechanical way as this.

That the sagitta and its underlying sensory patch is not the only sound-receptive mechanism in the squeteague may be inferred from the fact that after

both sagittæ are pinned down the squeteague will still respond occasionally to sound, but whether this response is through the sensory patch in the lagena or even in the utriculus, or through the skin, can not be stated. That it is from an organ far inferior to that in the sacculus is plain from its character, and hence, though there may be other parts of the body of the squeteague than the macula acustica sacculi that are sensitive to sound, this structure is certainly the chief organ in this respect.

It also seems fair to me to class the reactions of the squeteague to sound, when these reactions are mediated by the ear, under the head of hearing. While no sharp line can be drawn between touch and hearing, it seems to me that when any vertebrate can be shown to possess an ear which is stimulated by the vibrations of material particles it is fair to ascribe hearing to such an animal, and, for reasons already given, I believe this to be the case in the squeteague. I therefore reaffirm my former statement that certain fishes can hear, a statement that was based originally upon the conditions found by me in *Fundulus heteroclitus* (Parker, 1903a, 1903b) and confirmed in certain respects in other fishes by Zenneck (1903) and in the goldfish by Bigelow (1904). It does not seem to me that the very inadequate tests by Körner (1905) on some 25 fishes, with negative results so far as hearing was concerned, as well as the similar results of Lafite-Dupont (1907) can have great weight against positive results such as have already been obtained by other investigators, for it is comparatively easy in certain tests to find animals irresponsive to sounds by which they are certainly stimulated as shown by other methods (Yerkes, 1905). From the observations given in this section, I conclude that in the squeteague the sacculus with its contained sagitta is the chief organ of hearing and that these parts have nothing to do with equilibrium or muscle tonus. Although I agree with Hensen (1904) in ascribing hearing to fishes, I believe, for reasons already given, that the ears of these animals are also directly concerned with equilibrium.

SUMMARY.

1. The ear of the squeteague (*Cynoscion regalis*) is anatomically double in that it consists of (1) a utricular organ with its semicircular canals and (2) a saccular organ with its lagena. There is no utriculo-saccular canal.

2. The utriculus possesses a macula acustica recessus utriculi covered by an otolith, the lapillus, but no macula neglecta. Each of the three semicircular canals has a crista acustica without an otolith.

3. The sacculus possesses a macula acustica sacculi covered by a large otolith, the sagitta, and the lagena has a papilla acustica lagenæ covered by a small otolith, the asteriscus.

4. Squeteagues whose eyes have been covered with blinders usually swim with normal equilibrium. Squeteagues whose utriculi and semicircular canals

have been destroyed soon recover normal equilibrium. When the utriculi and semicircular canals are destroyed and the eyes are covered, the squeteagues swim with great irregularity and have all the appearances of having lost their equilibrium completely. Such fishes show marked muscular weakness, but respond to sounds as do normal individuals.

5. Squeteagues whose sagittæ have been pinned down against the non-nervous sides of their sacculi retain normal equilibrium and show no diminution of muscular strength, but they respond to sound to a slight degree only.

6. The utricular organ has to do with equilibrium and muscular tonus, and possibly, but not probably, with hearing.

7. The saccular organ has nothing to do with equilibrium or muscle tonus, but is the chief organ of hearing, a function in which the sagitta plays an essential part.

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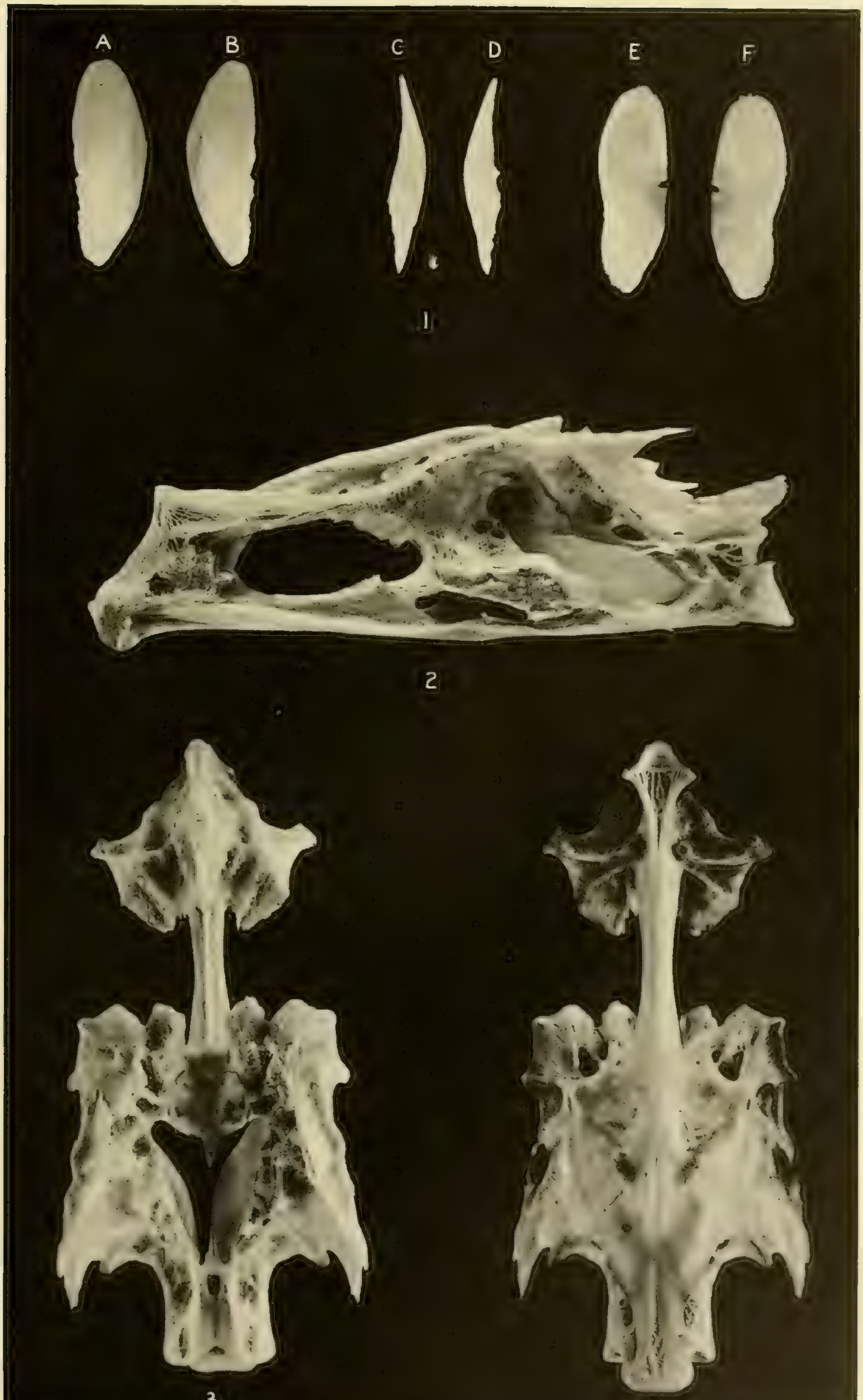
EXPLANATION OF PLATE.

FIG. 1.—Saccular otoliths (sagittæ) from the squeteague. All figures are placed with the anterior ends uppermost. *A*, *B*, median faces of a right (*A*) and of a left (*B*) otolith. *C*, *D*, dorsal edges of a left (*C*) and of a right (*D*) otolith. *E*, *F*, lateral faces of a left (*E*) and of a right (*F*) otolith.

FIG. 2.—Right half of the cranium of a squeteague viewed from the median face. The sagitta is shown in the bony capsule that partly surrounds the sacculus.

FIG. 3.—Dorsal view of the cranium of a squeteague. Much of the dorsal wall has been cut away to show the two bony capsules in which the sagittæ lie; the right sagitta is in normal position; the left one is turned out against what would be the nonnervous lateral wall of the sacculus.

FIG. 4.—Ventral view of the cranium of a squeteague, to show the bony capsules in which the sacculi are lodged.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AN INTENSIVE STUDY OF THE FAUNA AND FLORA OF A RESTRICTED AREA OF SEA BOTTOM

By Francis B. Sumner, Ph. D.

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AN INTENSIVE STUDY OF THE FAUNA AND FLORA OF A RESTRICTED AREA OF SEA BOTTOM.

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The preparation of detailed lists of the animals and plants occupying regions of greater or less extent has long been the favorite occupation of a certain class of naturalists. Such lists abound in the annals of botany and zoology. And it is only thus, indeed, that we have learned how our planet is populated. The cumulative labors, first of individuals, then of scientific organizations and of governments, have given us the data from which to formulate the laws of geographical distribution. In the beginning we have the bare facts of occurrence; then correlations are established between given conditions of environment and the presence of given species or varieties; finally, we are brought within striking distance of the great central problem of the origin of species. So much for the scientific aspect of the case. On the practical side, faunistic studies need offer no apology for their existence. They have, indeed, formed a part of the established policy of our government for many years. The Department of Agriculture has long maintained a biological survey of the land animals and plants of this continent, while our Bureau of Fisheries has slowly but steadily been conducting a census of the inhabitants of our seas and lakes. Truly, these creatures are not all fit for food, nor indeed for any commercial purpose whatever—though we must add that there are probably many more animals and plants of economic value than we now realize. But the life of the sea is an interrelated whole. One species stands in relation to another as its enemy, prey, food, parasite, host, messmate, or the like, and intimate chemical relations may exist, as we find between the animal kingdom and the plant kingdom as a whole.

Moreover, as we now view the case, all these multitudinous living creatures are, so to speak, related by "blood." What we learn of one is commonly applicable to its nearer relatives and frequently to a long series of other forms.

Hence the futility of endeavoring, even on economic grounds, to restrict our investigations to food fishes or other animals of obvious commercial importance. What we discover from the study of a "minnow" is, in the great majority of cases, quite as applicable to a mackerel or a cod. But the minnow is easier to obtain and easier to manipulate. A few years ago an expert in the employ of the Bureau of Fisheries investigated the hearing of fishes. His experiments were concerned chiefly with a little fish of no seeming importance whatever. He cut its nerves and, worse yet, played musical notes at the helpless creature! Could anything seem less practical or less worthy of the attention of serious-minded persons? Recently the fishermen of certain sections of our coast have been stirred up by the alleged effects of naval target practice and of the noise produced by motor boats in driving away fishes from their customary haunts. To whom does the Bureau appeal to settle this problem? Naturally to the man who knows most about the hearing of fishes. The matter is tested, and the problem—or one phase of it, at least—is settled very briefly. The motor boats are found to be innocuous—at any rate to the fishes. Regarding the cannon, a decisive answer is likewise hoped for soon. But this is taking us a long way from the biological survey of the Woods Hole region.

Years ago Woods Hole was selected by Professor Baird as the most promising spot upon our coast for the commencement of a scientific study of fisheries problems. From the very outset he gathered about him a staff of naturalists of the type that was dominant in that generation—men eager to seek out every living thing concealed beneath the waves, to describe and figure and name. Accordingly, the first volume published by Baird as Commissioner of Fish and Fisheries contains not only a catalogue of the fishes of the east coast of North America, but an extended report upon the invertebrate animals of Vineyard Sound and adjacent waters and a list of the marine algæ found in this same region. In spite of the previous labors of Desor and Adams and Gould and Leidy and Stimpson and Perkins and the two Agassiz, who had already made essays into the waters of southern New England, Verrill and Smith found in Vineyard Sound and Buzzards Bay a practically virgin field. We begin to realize the pioneer nature of much of their work when we recall that even some of our most abundant and familiar species—e. g., the sponge *Chalina arbuscula*, the tube-worm *Hydroides dianthus*, the shrimp *Virbius zostericola*, and the beach flea *Orchestia agilis*—were first described in the Report upon the Invertebrate Animals of Vineyard Sound. And, indeed, this report, hasty and ill-digested as it was, remains to this time our chief single reference work upon the fauna of this section of our coast. That first inclusive list of local species has been much extended, it is true, partly by the original authors, partly by a more recent group of naturalists, who have prepared for the Bureau of Fisheries a series of monographic reports upon certain phyla or classes of animals.

The undertaking of which it is my privilege to speak to you was commenced in the summer of 1903.[a] The project was twofold: First to make as complete a census as possible of the marine fauna and flora of an arbitrarily limited region within the vicinity of Woods Hole, Mass. (fig. 1);[b] and secondly, to carry on systematic dredging operations throughout that portion of this region comprising Vineyard Sound and Buzzards Bay. For the former division of the work we have resorted for data to all previous published reports, to copious manuscript notes which have been furnished us by various investigators, to the wealth of information accumulated during many years past by the veteran collector of the Bureau of Fisheries, Mr. Vinal N. Edwards, as well as to original records from our own operations. The final product, a much elaborated check list, is nearly ready for press. But it is the second part of this project to which I shall invite your attention. The method of procedure here employed was to dredge at rather frequent intervals throughout the entire extent of Vineyard Sound and Buzzards Bay. Each of these dredging stations was numbered, and was definitely located upon our charts, and the total "array" of animals and plants from each point was determined. From such records it was of course possible to plot out the distribution of every animal and plant encountered, granting, of course, the thoroughness and reliability of our methods and the accuracy of our determinations of species. It will be impossible here to enter into a discussion of the methods employed or of the trustworthiness of our data. It is sufficient to state that a full report upon this entire undertaking is nearly ready for press, and that due allowance has been made for all possible sources of error. It is my present purpose merely to give a brief statement of a few of the more interesting results.

To begin with, the waters which have been explored are exclusively shallow ones, at no point exceeding 25 fathoms in depth. Accordingly, none of the characteristic deep-sea deposits and none of the abyssal types of animals have been encountered. Within the limits stated, however, we have dealt with a wide diversity of conditions. Among these are to be mentioned differences in the character of the bottom, in the temperature, salinity, depth, and purity of the water, and in the tidal currents. Foremost among the conditions determining the distribution of the bottom-dwelling organisms we have found to be the character of the bottom, considered chiefly in relation to its physical texture. It is a mere platitude to state that fixed animals require a solid basis for attachment, and burrowing ones a suitable medium for excavation. Drifting sand is of course unfavorable to the growth of many forms, and soft mud

[a] This work has been conducted for the Bureau of Fisheries by the present author in cooperation with R. C. Osburn and L. J. Cole (zoology), and B. M. Davis (botany). A large number of specialists have likewise rendered assistance in identifying specimens, revising terminology, etc.

[b] Roughly, from Newport to Monomoy, and from the mainland of Massachusetts to the 20-fathom line.

doubtless interferes with the respiratory currents of many others. Since Vineyard Sound and Buzzards Bay are rather sharply distinguished from one another by the presence or absence of mud on the one hand and of clean sand and gravel on the other (pl. CXXIV), it is natural that the most obvious distinction in distribution should be that between the predominantly sound-dwelling species and the predominantly bay-dwelling ones. The former, it must be added, greatly preponderate over the latter numerically. Within each of these large bodies of water the local distribution of many forms is very obviously determined by the occurrence of one or another variety of bottom. Thus it happens that many species whose occurrence in Vineyard Sound is general are found in Buzzards Bay only in the adlittoral zone, particularly along the Elizabeth Islands (fig. 6). Here the mud is less prevalent, and bottoms of clear sand and gravel are frequently met with.

A type of distribution which is almost the converse of the last is encountered in the case of certain mud-dwelling species which are of general occurrence throughout the bottom of Buzzards Bay, but which in Vineyard Sound are confined to a few definite areas where mud is known to be present (e. g., the annelid *Clymenella torquata* and the bivalve mollusk *Yoldia limatula*, figure 7 and 8). Furthermore, Vineyard Sound is roughly divisible into an eastern half, in which the bottom is predominantly stony and gravelly, and a western half, in which the bottom is mainly of sand. Accordingly, many species, particularly attached forms (fig. 9), are scarce or absent in the western half of the Sound, except in the littoral and sublittoral zones, while certain sand-dwelling forms, among which we may name the rays and the flounders among the fishes (fig. 10, 11), and the lady-crab (*Ovalipes ocellatus*), are especially common in that very region. The lower end of Buzzards Bay is comparatively free from deposits of mud, and accordingly we often meet with species here which are generally distributed in the sound, but which are scarce or absent from the more central parts of the bay. The scarcity or apparent total absence in Buzzards Bay of many local species of animals representing every phylum, is, we believe, due chiefly, if not entirely, to the character of the bottom.

The temperature factor, with little doubt, is a controlling one in determining the distribution of many species within the limits of our chosen region. We encounter a large number of animals, belonging to practically all the subkingdoms, and likewise certain plants, whose distribution in local waters is confined to the western end of Vineyard Sound and the mouth of Buzzards Bay (fig. 13, 14, 15, 17, 27). Here the water temperature at the bottom averages during the summer months about 10° F. (5.6° C.) lower than at Woods Hole and in the less exposed waters of the region. (Fig. 2.) The mean bottom temperature at 14 stations in the western third of Vineyard Sound and just without the latter, at a time when it was probably near its maximum, was found by us to be 60.2° F. (15.7° C.).

This temperature is exceeded at Woods Hole during that portion of the year between June 3 and October 12 (diag., pl. CXXIII). It thus appears that the summer conditions of temperature, such as obtain in the vicinity of Woods Hole during the months of June, July, August, and September, do not directly affect the western half of Vineyard Sound, and in only a limited degree the lower end of Buzzards Bay.

A few words are necessary here regarding the hydrography of this section of the New England coast. As is well known, the Gulf Stream courses in an approximately northeasterly direction, at a distance of about 100 miles south of Long Island, Marthas Vineyard, and Nantucket (fig. 1). That this great body of warm water must affect the temperature of the surface strata, at least in Vineyard Sound and Buzzards Bay, is rendered probable by the fact that large masses of the floating *Sargassum*, or "gulf weed," with their attendant animal life, are driven thither nearly every season by prolonged southerly gales. It is likewise generally believed that between the Gulf Stream and the southern coast of New England there passes another more or less well-defined current, having its origin in the far north. That the water of this colder current is diffused by the tides along its coastward margin and affects the temperature of the outlying waters of our region, especially at the bottom, can hardly be doubted.[a]

With few exceptions, those species whose occurrence locally is confined to these colder waters are known to be primarily northward-ranging types, which are here near the southern limit of their distribution, so far, at least, as such shallow waters are concerned. Many of these same species have likewise been encountered by us at Crab Ledge, off the southeastern bend of Cape Cod, and some of them likewise on the shoals to the eastward of Nantucket. Certain other forms (fig. 18, 26), though elsewhere of general distribution, are absent from just those waters to which these northern types are restricted. Such appear to be, for the most part, southward-ranging types, which find their northern limit in Cape Cod. The numerous species (fig. 5 and many of the others) which are of general distribution throughout the waters of the region, or which, at least, do not appear to be restricted as regards the temperature of their medium, are more commonly either species with an extended range in both directions up and down the coast or with a southward range only. The truly northern types are less likely to show such a general distribution in Vineyard Sound and Buzzards Bay. It is impossible to state at present how the temperature factor is effective in limiting the distribution of species locally. Our thermometric determinations seem to show that the temperature of those waters which immediately join the ocean is lower than elsewhere for probably not much more than half of the year, the difference being greatest during the summer

[a] See report by Libby in Bulletin of the U. S. Fish Commission, vol. IX, 1889 (1891) p. 391–459; also address before the Fourth International Geographical Congress, London, 1895. It must be added, however, that the existence of such a cold current off the New England coast is now questioned by some authorities.

months. It is likely that all the waters of the region approach very nearly to the freezing point of salt water for a longer or shorter period nearly every winter. It may be that the rule which has been formulated by Verrill[a] and Allen for birds, and by Merriam[b] for terrestial animals and plants in general, applies here—namely, that the limits of distribution are determined by the temperature at the breeding season only. If this be true it would follow that adult animals and plants might survive temperatures in which propagation could not occur.

It is certain, however, that an actual destruction of adult organisms may occur as the result of a too high or too low temperature. The case of the common sea urchin (*Arbacia punctulata*), which, as our records show, was almost exterminated in Vineyard Sound during the particularly cold winter of 1903–4[c] is a good illustration of this point; and it is a matter of common observation among fishermen that great numbers of dead fishes of certain species are frequently found during the thaw following a particularly hard spell of cold weather.[d] Conversely, certain members of our local fauna (e. g. the noncolonial hydroid *Tubularia couthouyi*) are known to be able to grow and maintain an active existence only at a low temperature. It is manifestly impossible, therefore, to make any single, all inclusive statement as to mode of operation of temperature in restricting the distribution of species in the Woods Hole region.

As regards the depth factor, we can find little evidence of actual bathymetric distribution in the waters under consideration. It is true that certain species, according to our dredging records, seem to be restricted to the sublittoral zone (e. g. *Crepidula convexa*, fig. 23), but these are probably also littoral in their habitat, and it is possible that proximity to shore rather than depth proper may be the determining factor in such cases.

Salinity, likewise, though undoubtedly a potent factor in determining the distribution of species in or near the mouths of streams, seems to play a negligible part in the explanation of our dredging records. The only point in the region covered where the dilution of the sea water is at all considerable is near the head of Buzzards Bay (fig. 4); but we have recorded hardly a single species which was dredged here exclusively or even predominantly.

One question which will naturally present itself to the student of geographical distribution is this: What is the position of the Woods Hole fauna in the fauna of our American coast? To which of the larger zoogeographical regions does it belong? And is it situated in the middle of that region or close to one of its

[a] American Journal of Science, March, 1866, p. 249.

[b] North American Fauna, no. 3, p. 26; Proceedings of the Biological Society of Washington, April, 1892, p. 45.

[c] The mean water temperature at the Woods Hole station for January and February, 1904, was 29.3° F., that for the same months during the other four years of the period 1902 to 1906 being 32.3°.

[d] Gould cites a case of the wholesale destruction of oysters by "ground frost" (see Boston Journal of Science, 1840, p. 492).

limits? In other words, do the majority of species have a range which extends mainly to the northward along this coast, or do the majority have, on the whole, a southward range; or is there no appreciable preponderance of one sort over the other? Simple as these questions may seem, it is difficult to give an answer that is at all satisfactory. The known range, as distinguished from the actual range, of a species, is very frequently determined by historical accident. Thus the Bay of Fundy, Massachusetts Bay, Woods Hole, New Haven, Charleston, etc., frequently figure in our literature as limits of distribution, and this for obvious reasons. Similarly, Cape Cod has taken a conspicuous place as a limit of distribution in all the accounts of our Atlantic Coast fauna and flora. In fact, it has been pretty generally assumed that Cape Cod forms a rather definite boundary between the fauna and flora inhabiting the regions above and below it. This was urged by Gould[a] as early as 1840, and has been maintained by Dana, Verrill, S. I. Smith, and others for the animal kingdom, and by Harvey and Farlow for plants. The faunal region extending to the southward of this barrier has been termed the Virginian, that to the northward the Acadian,[b] Woods Hole and the adjacent waters being assigned to the former. While it would be vain to dispute the importance of the barrier formed by Cape Cod and the outlying islands and shoals, together with the temperature conditions associated with them, it seems probable that its significance has often been exaggerated, owing to the historical prominence of this region of the coast in the annals of American zoology and botany. Some facts are herewith offered in support of this opinion.

Of the 202 species of animals which have been taken at 10 or more of our dredging stations, and which, therefore, may be regarded as representative of our local marine fauna, 100, or almost exactly 50 per cent, are reputed to have a range on our coast which is predominantly southward. By this it is meant that the extent of their known range to the southward is at least twice that of their known range to the northward. On the other hand, 48 of the species (24 per cent) have a range which is predominantly northward, while 29 of them (14 per cent) have a range of approximately equal extent (so far as known) in both directions. The remaining 25 species have been relegated to the doubtful column, owing to the unsatisfactory nature of the data at our disposal; some of these forms having been found only in the vicinity of Woods Hole. The fact to be emphasized is that the ratio of southward-ranging species (as thus defined) to northward-ranging species is approximately two to one, while about 14 per cent of them do not seem to be thus restricted in latitude.

Viewing these 202 species in another way, it is to be noted that 129, or about 63 per cent of them, are known to have a range extending north of Cape Cod,

[a] Boston Journal of Natural History, vol. III.

[b] See particularly Verrill, in Proceedings of the Boston Society of Natural History, vol. X, 1866, p. 333-357.

leaving only 37 per cent which, so far as reported, have not transcended this barrier. Doubtless more complete information will reduce the latter figure. As has already been pointed out, any locality where extensive collecting has been done is sure to figure as the reputed limit of distribution—whether northern or southern—for many species. It is significant, therefore, that only 40 of the species under consideration (20 per cent) have not yet been recorded from points south of Woods Hole.[a] Comparing this figure with the 37 per cent which are not known to occur north of Cape Cod, it may be that we have some measure of the real effectiveness of the last as a barrier to distribution.

It must be conceded at once that it is impossible to form a just estimate of the geographical range of a species from any mere statement, however correct in itself, of the extreme limits of its distribution. The bathymetric range and other factors of its habitat at various latitudes must be taken into consideration. It is obvious, likewise, that the same importance must not be attributed to the isolated and occasional occurrence of a given species as to its occurrence at points where it is widespread and abundant. But in most of the published tables which are available for consultation no distinction is made between the two.

Crude in the extreme, therefore, as any such computations must be, the conclusions seem to be fairly well grounded (1) that Cape Cod does have an appreciable influence as a barrier to distribution, and (2) that the southern types preponderate considerably over the northern ones in our Woods Hole fauna, or at least such of it as is accessible to the dredge. These generalizations may not be true of each individual group (e. g., coelenterates and amphipods); and in general it must be remembered that a considerable minority of northern forms are included in our local fauna, while more than 60 per cent of our species are known to occur north of Cape Cod. On the other hand, it is well to add that our local fish fauna, which is but sparingly represented in our dredging records, and consequently plays little part in the foregoing tabulation, is overwhelmingly southern, 75 per cent being southward-ranging in the foregoing sense of the term, while nearly 50 per cent of the total number of recorded species are such as are reputed to find in Cape Cod their northern limit of distribution. And, lastly, we must bear in mind that we are here dealing only with the *benthos* of the region, the plankton, as well as the littoral fauna, being left out of consideration.[b]

Turning now to another phase of our results, the comparative distributions of different species of the same genus are presented by us in a large number of cases (e. g., *Pecten*, *Asterias*, *Crepidula*, *Pagurus*, fig. 16, 17, 20–27). In some cases, two such species have a practically coincident distribution, as regards both

[a] More strictly, south of Vineyard Sound and Buzzards Bay.

[b] Of the total number of 1,600 (±) species of animals recorded for this region, only 500 (+) have been taken during our dredging, and of these less than half have been employed in the above computations.

extent and frequency; in other cases, one is of much greater abundance than the other, though their range of distribution is practically the same; in others still, one has a much more restricted range than the other. As instances of the last condition we may mention the two common starfishes, *Asterias forbesi* and *A. vulgaris* (fig. 20, 21), or the two chestnut shells, *Astarte castanea* and *A. undata*. In each of these examples the two related species overlap throughout a part of their range, but the range of one is more restricted than that of the other.

Whether or not the specific differentiation preceded or followed such a change of habitat is not even suggested by any of the facts which we have encountered. Who can say, for example, whether the tendency to restrict itself to muddy bottoms preceded or followed the differentiation of the amphipod crustacean *Ampelisca macrocephala* as a species distinct from *A. spinipes?* Yet this is the kind of data with which we have to deal. Nevertheless, the bare fact that various closely related species do show decidedly different distribution patterns is one of great interest, for it shows that the slight morphological differences by which the species are distinguished from one another are oftentimes correlated with marked physiological differences, sufficient to adapt the two to differing habitats. Thus the assertion so often made that the slight structural differences by which we distinguish one species from another are commonly of no conceivable utility, and therefore can never have arisen through the action of natural selection, loses much of its force. While it may be true that these slight structural differences in themselves can play no significant rôle in the life of the organisms concerned, it is likewise evident that there are certain correlative physiological changes sufficient to adapt the organisms to somewhat different modes of life. That natural selection has been the controlling factor in the origination and perpetuation of such specific differences, whether morphological or physiological, is far from certain. But that the characters concerned are in most cases too insignificant to be of selective value is also far from certain.

To the reader who would demand an exact economic equivalent for the labor and money here expended our answer must be a more general one. Science and industry move together. Industry is helpless without the aid of science, and the greatest industrial progress is at present being made by those countries which realize this fact most fully. But science can never prosper if forced to play the rôle of a servant. She must be free to pursue her own ends without being halted at every step by the challenge: *cui bono?* The attempt to restrict our scientific experts to problems of obvious economic importance would be equivalent to depriving ourselves of their services altogether. It is to-day accepted as a commonplace that all the great discoveries of practical value have rested ultimately upon principles first brought to light by the student

of nature. The enlightened manufacturer of Germany looks upon a well-paid scientific investigator as a good investment. As a result of this policy the rest of the world is looking on uneasily while its own industries pass into the hands of this far-sighted competitor. Great Britain and the Scandinavian countries, the great fishing nations of Europe, have long been leaders in the scientific investigation of the sea. And in recent years we have witnessed the formation of an international council, representing all of those nations having an immediate interest in the fisheries of the North Sea, and organized for the study of hydrographic and biological problems as well as of purely economic ones. To Americans there should be no novelty in all this. Let us keep in mind the oft-quoted words of the distinguished founder of our Fish Commission in outlining the policy adopted by him:

> As the history of the fishes themselves would not be complete without a thorough knowledge of their associates in the sea, especially such as prey upon them or in turn constitute their food, it was considered necessary to prosecute searching inquiries on these points, especially as one supposed cause of the diminution of the fishes was the alleged decrease or displacement of the objects upon which they subsist.
>
> Furthermore, it was thought likely that peculiarities in the temperature of the water at different depths, its chemical constitution, the percentage of carbonic-acid gas and of ordinary air, its currents, etc., might all bear an important part in the general sum of influences upon the fisheries; and the inquiry, therefore, ultimately resolved itself into an investigation of the chemical and physical character of the water and of the natural history of its inhabitants, whether animal or vegetable. It was considered expedient to omit nothing, however trivial or obscure, that might tend to throw light upon the subject of inquiry, especially as without such exhaustive investigation it would be impossible to determine what were the agencies which exercised the predominant influences upon the economy of the fisheries.

So that if we can not, from our present labors, offer any suggestions of direct value to the practical fisherman, we trust that we have at least added to the intelligent understanding of the marine life of our coast. And we likewise trust that the ultimate benefit to the practical fisherman will be as great as that to the man of science.

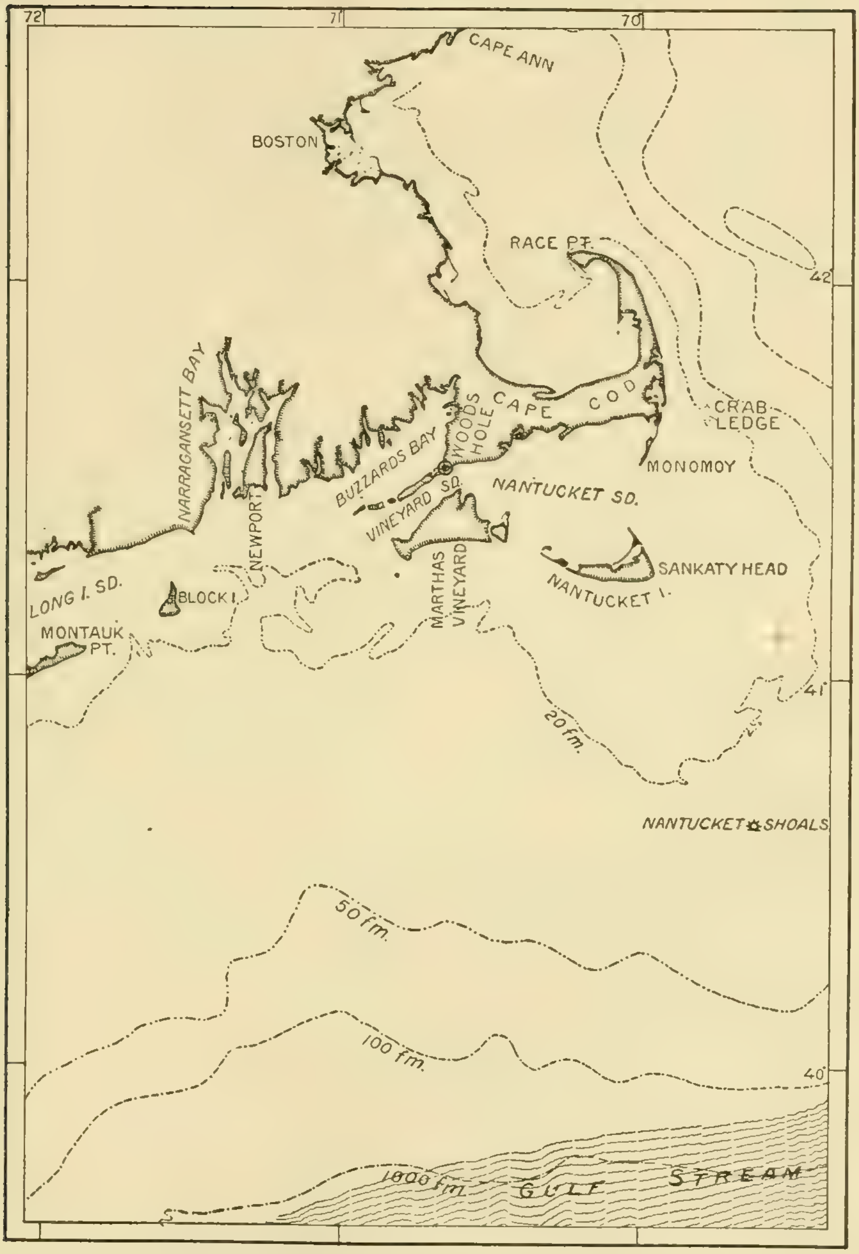


FIG. 1.—Map showing Woods Hole region and adjacent portions of the New England coast.

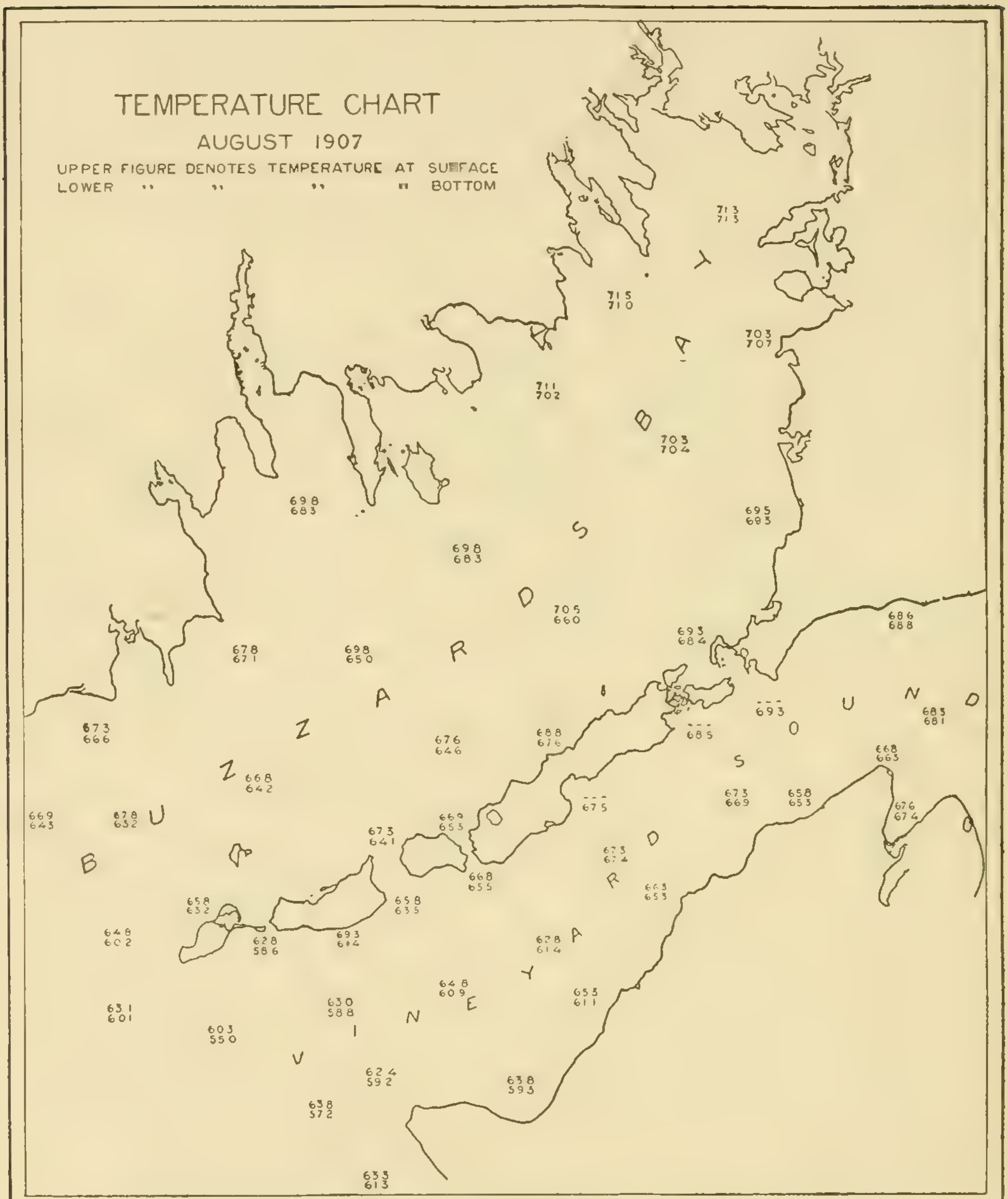


FIG. 2.—Chart showing temperature throughout Buzzards Bay and Vineyard Sound in August.

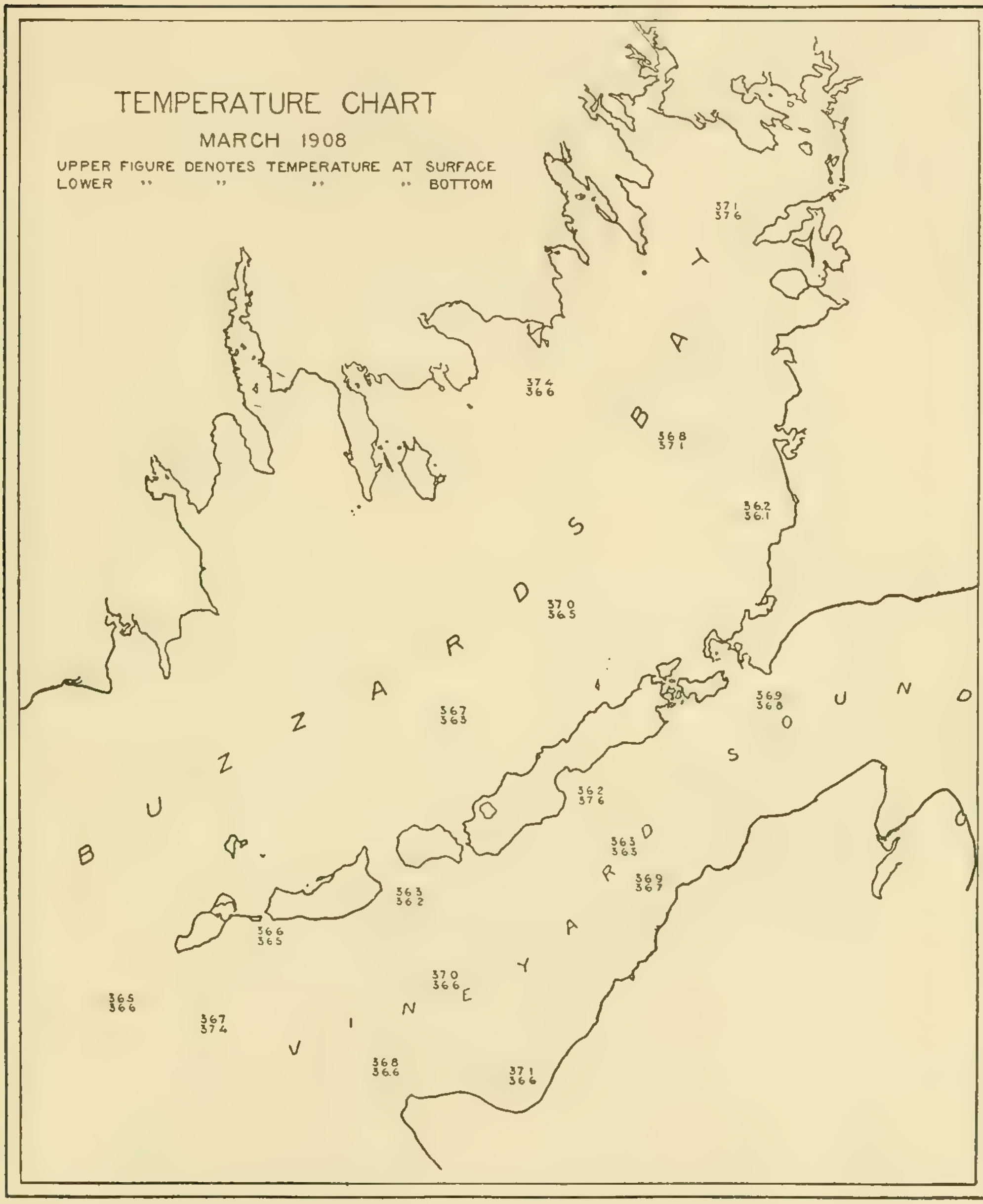


Fig. 3.—Chart showing temperature throughout Buzzards Bay and Vineyard Sound in March.

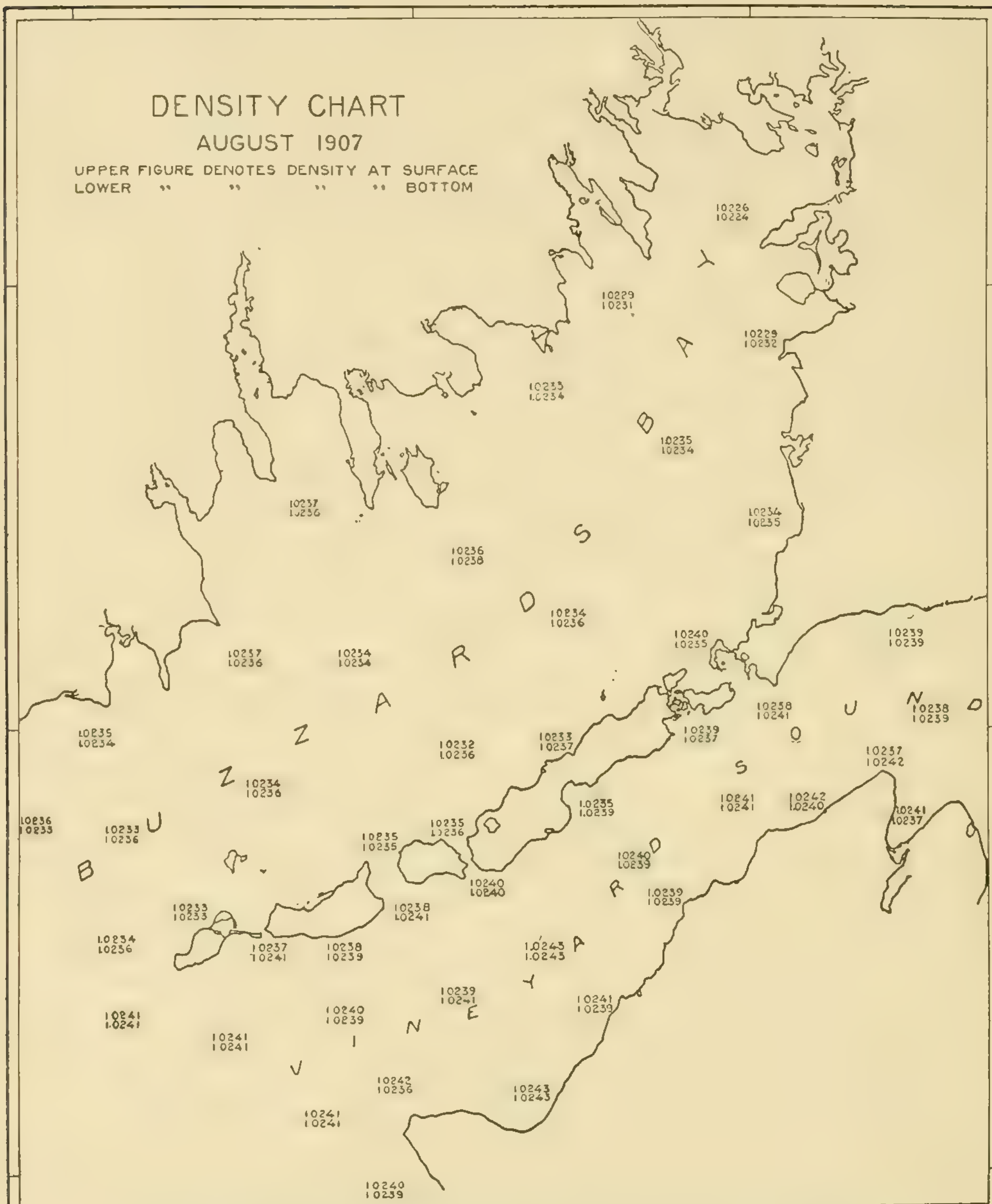


FIG. 4.—Chart showing density throughout Buzzards Bay and Vineyard Sound in August.

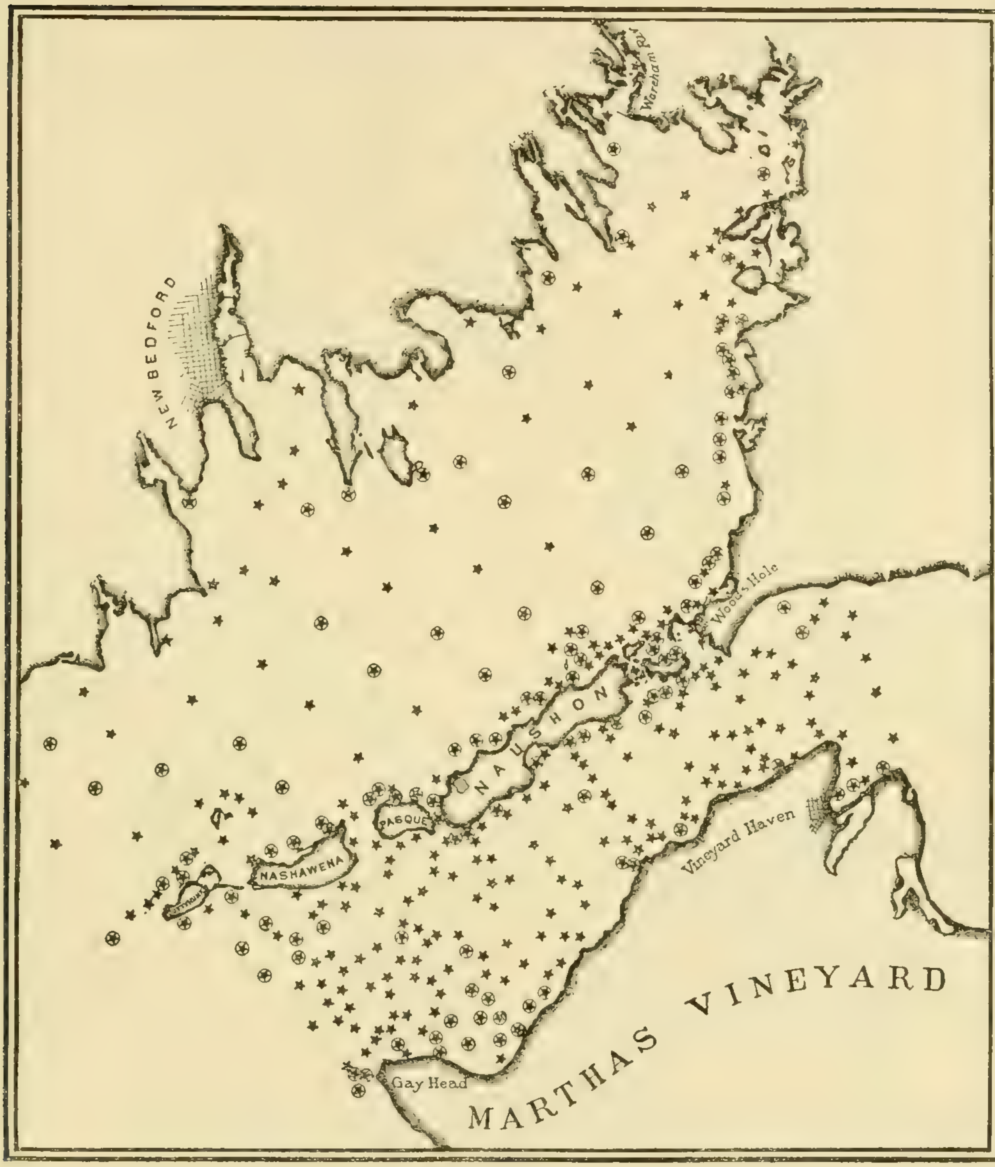


FIG. 5[a].—Local distribution of the gastropod mollusk *Tritia trivittata*. This species was recorded from 353 stations out of the total of 417 comprised within the limits of the map. It has thus the most general distribution of any species of animal dredged within these waters.

[a] The circle around the star, here and elsewhere among the mollusks, denotes the known occurrence of *living* specimens. Where the circle is wanting, either dead shells only were present or the point is not indicated in the records. This symbol has, however, been employed only in the case of shell-bearing animals.

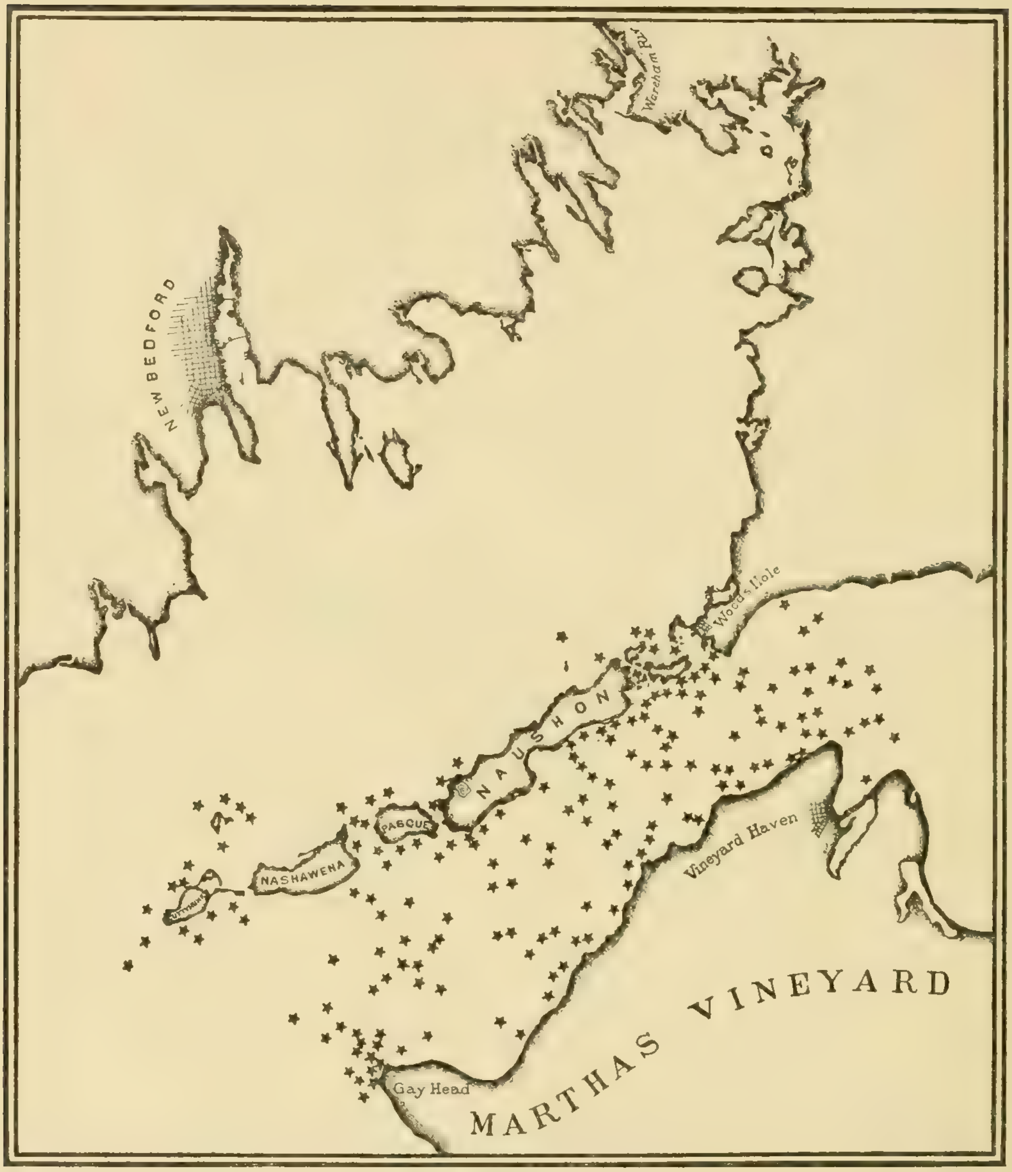


FIG. 6.—Local distribution of the polychaetous worm *Nereis pelagica*. Of general occurrence in Vineyard Sound; in Buzzards Bay mainly restricted to adlittoral zone, along the Elizabeth Islands. An example of distribution determined by the character of the bottom.

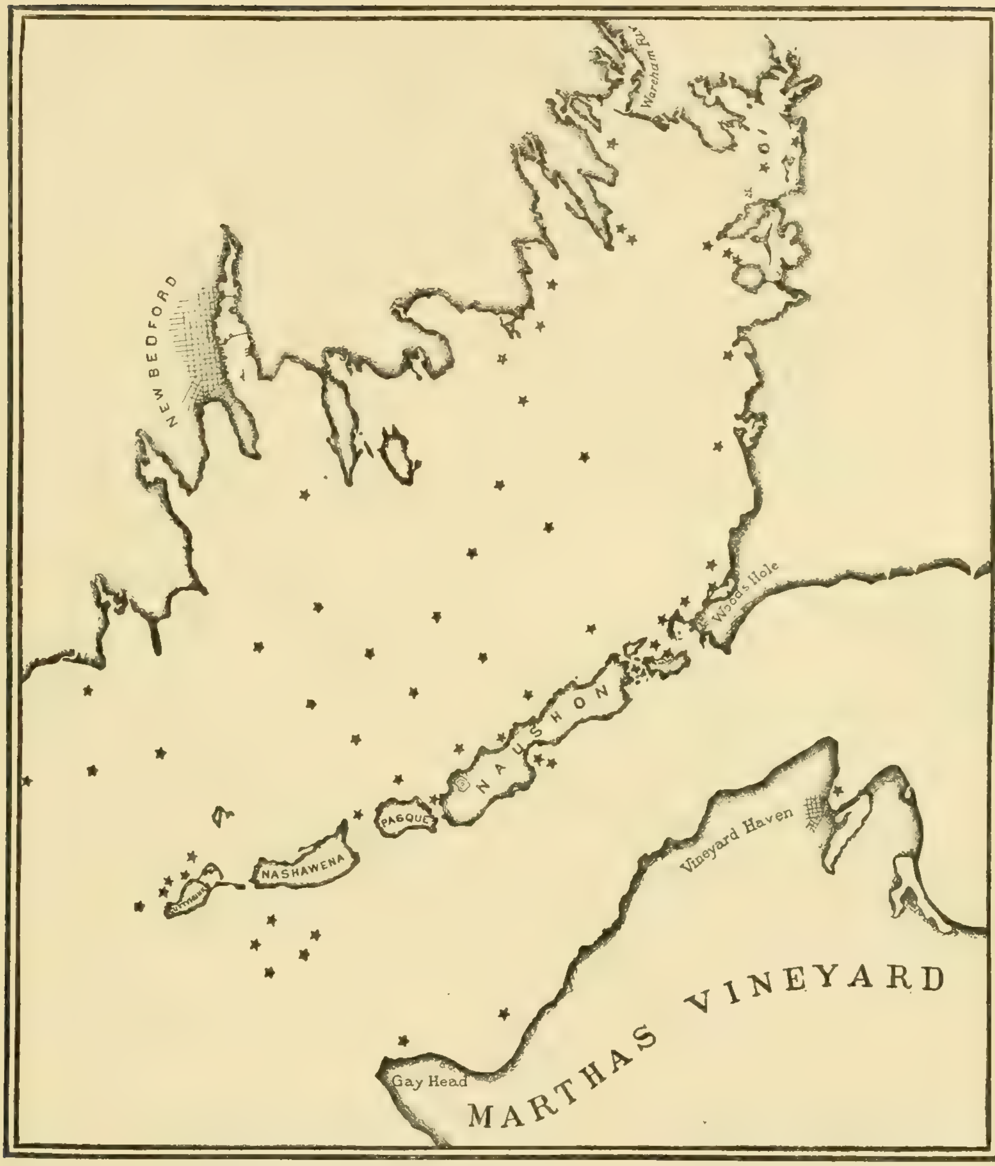


FIG. 7.—Local distribution of the polychaetous worm *Clymenella torquata*. This is likewise determined by the character of the bottom, but is almost the converse of that of *Nereis pelagica*, the present species being in a large degree restricted to a muddy habitat.

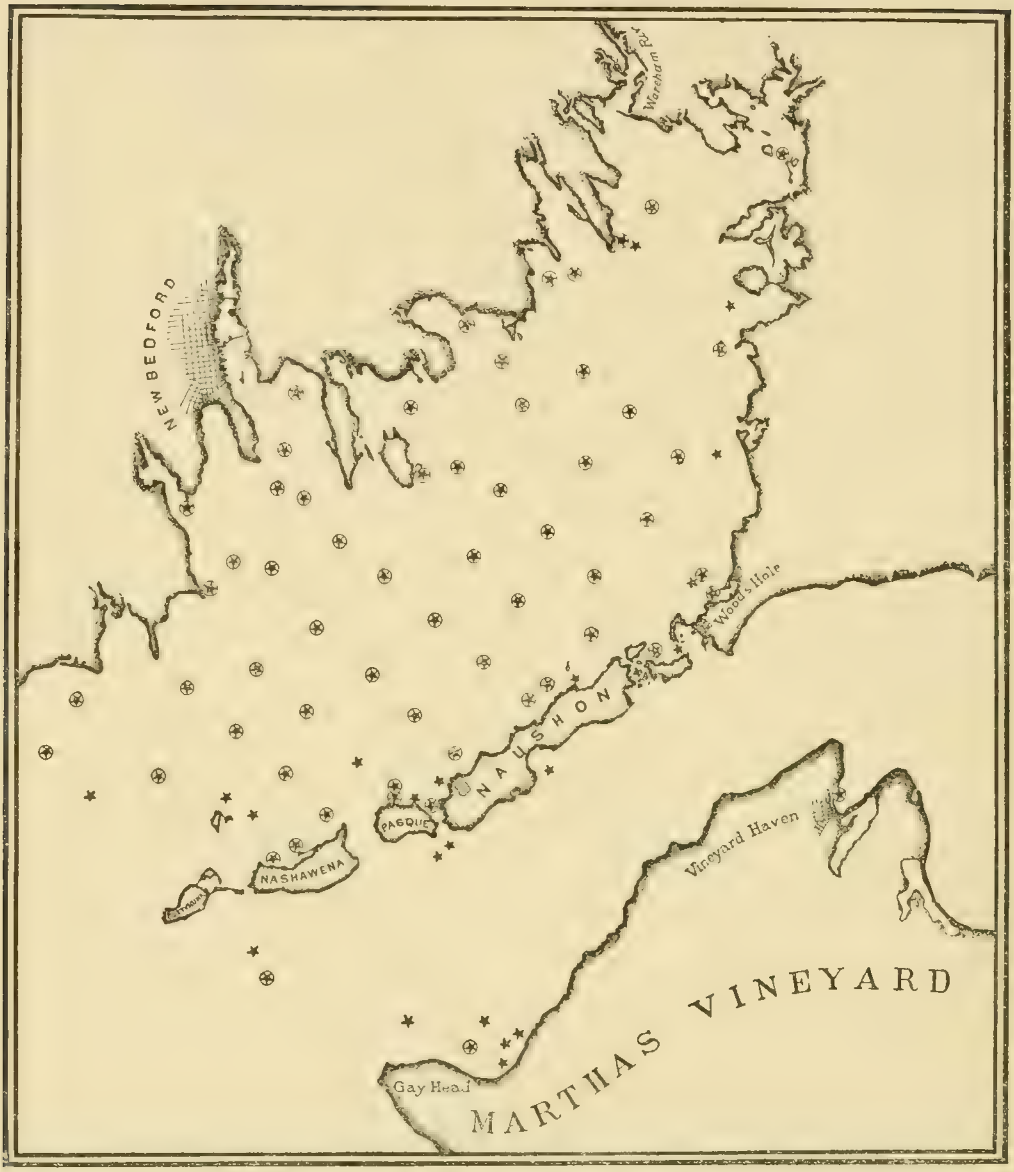


FIG. 8.—Local distribution of the bivalve mollusk *Yoldia limatula*, another mud-dwelling species, chiefly restricted to Buzzards Bay.

FIG. 9.—Local distribution of the sertularian hydroid *Thuiaria argentea.* The colonies of this species are almost invariably attached to stones and shells; hence the distribution is determined by the character of the bottom.

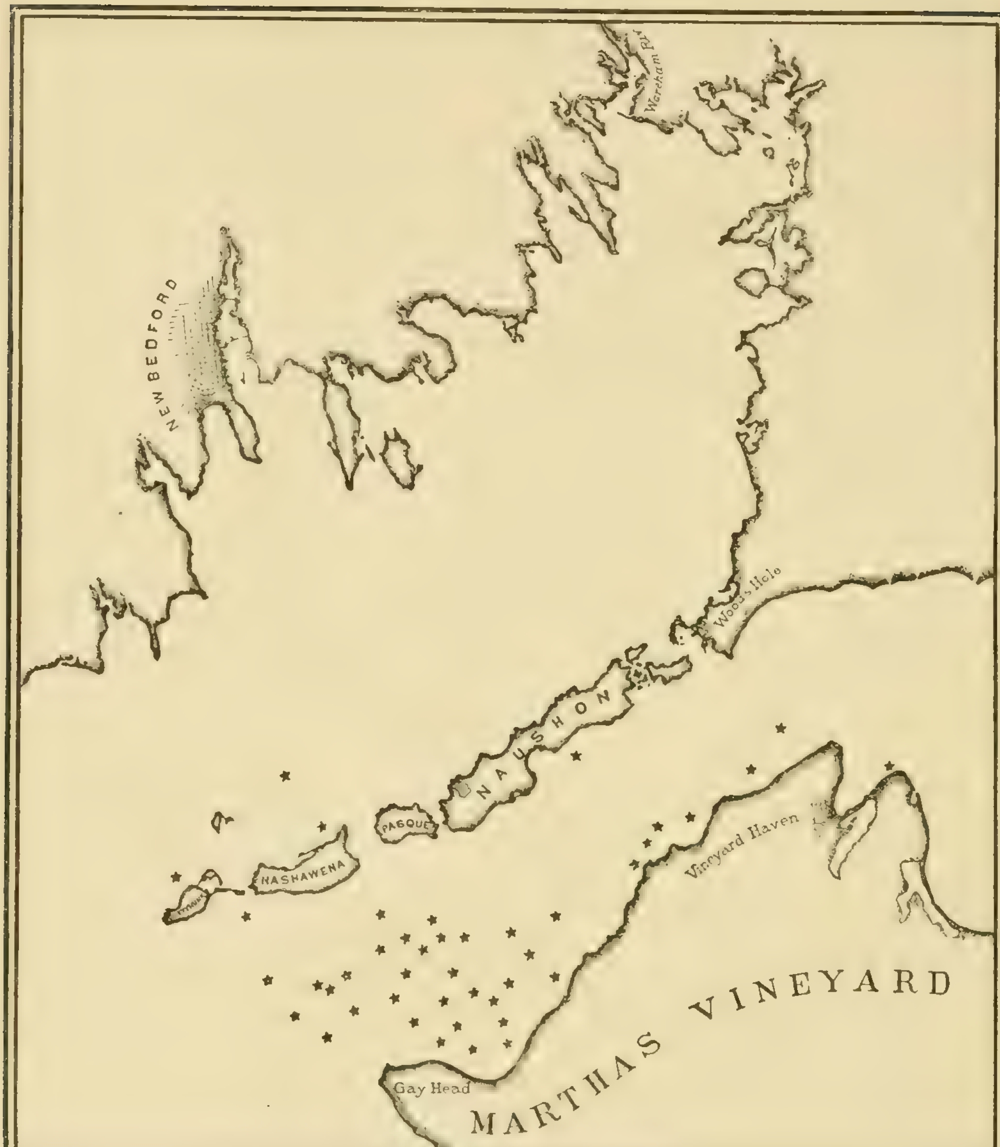


FIG. 10.—Local distribution of the common skate, *Raja erinacea*, a fish adapted to life upon sandy bottoms.

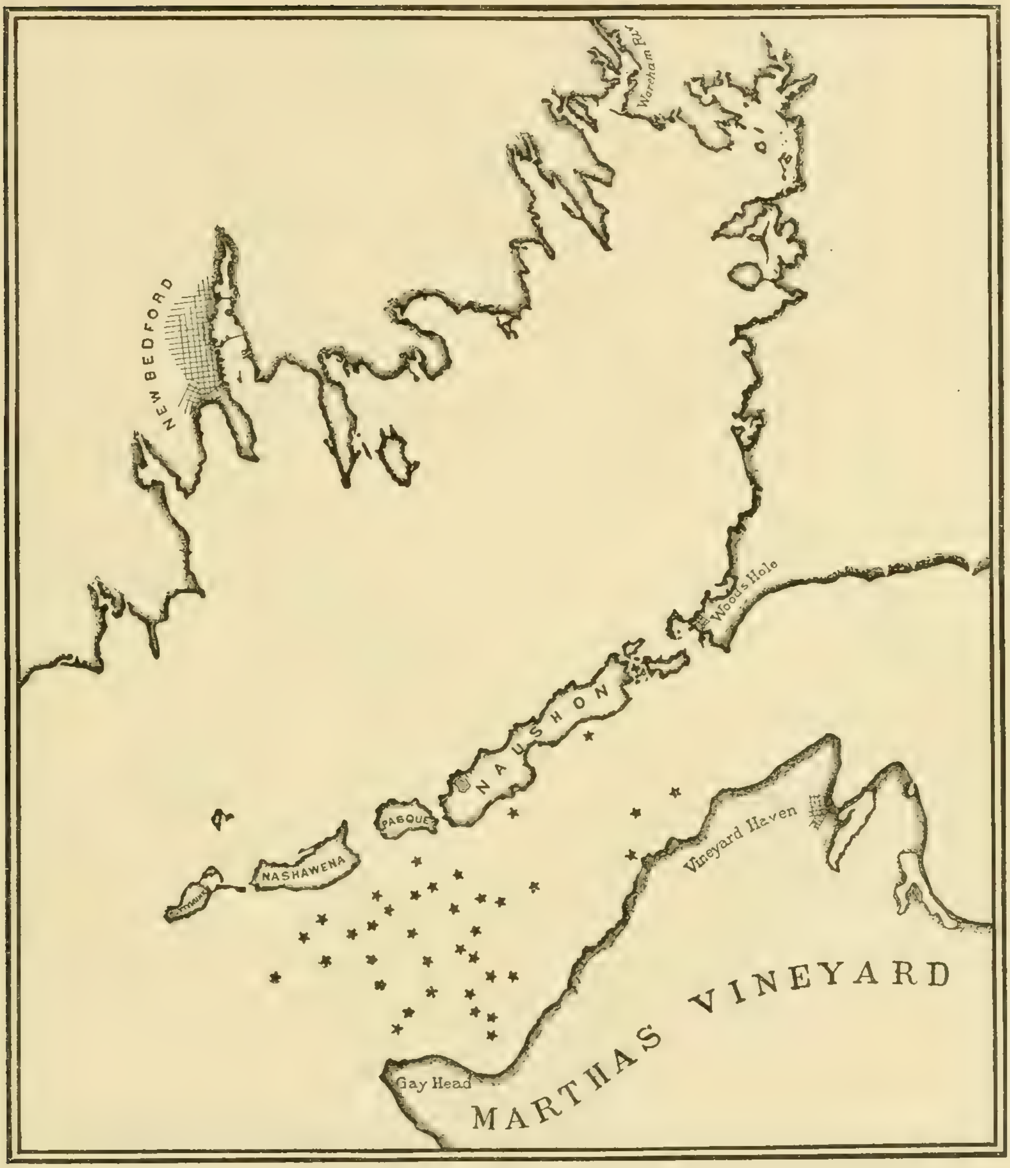


FIG. 11.—Local distribution of the "window-pane" flounder, *Lophopsetta maculata*. This is likewise a bottom-dwelling fish restricted to sandy places.

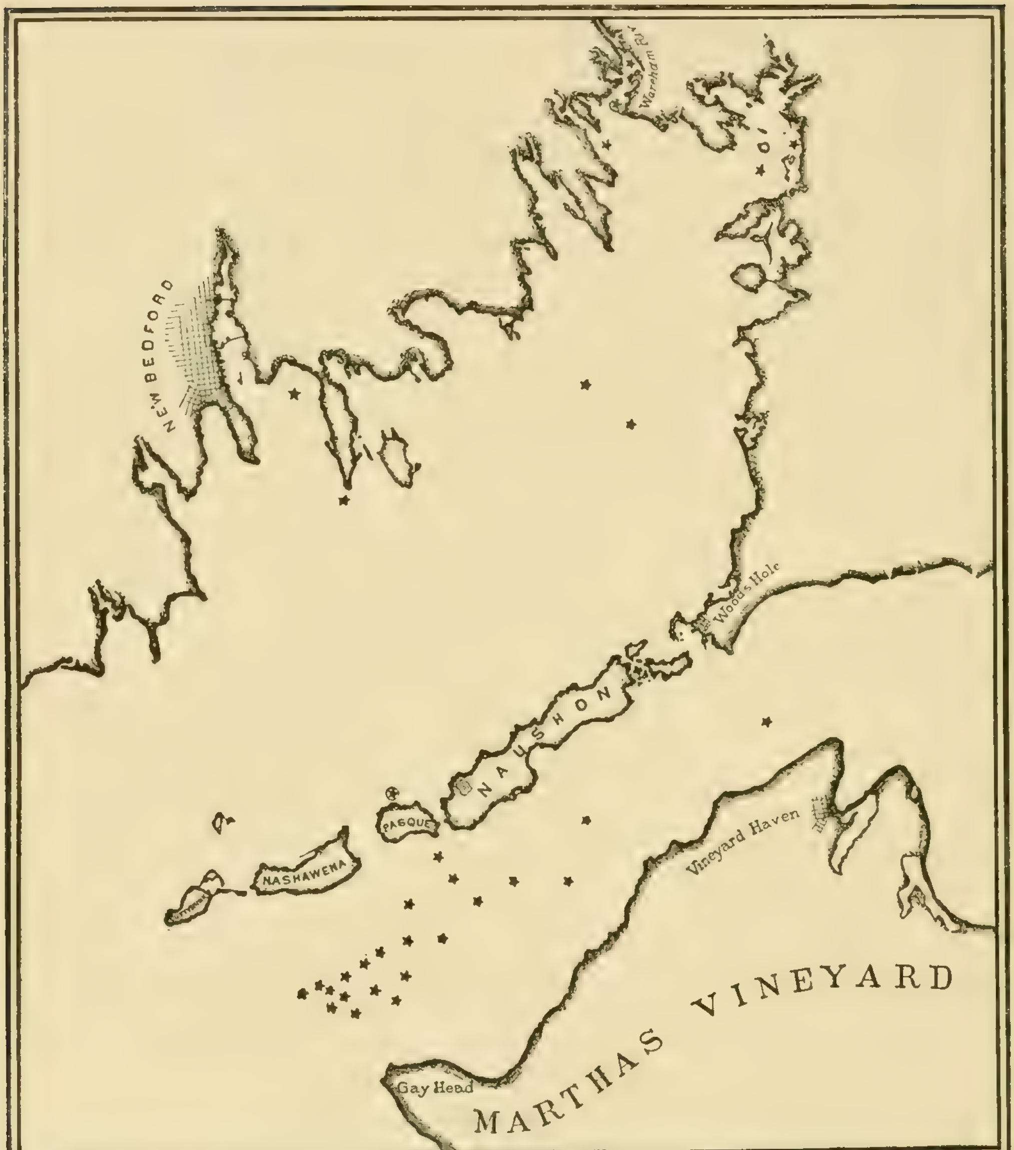


FIG. 12.—Showing localities at which the oyster, *Ostrea virginica*, or its shells, were taken. This is a good example of a spurious distribution pattern, since the shells in the main channel of Vineyard Sound were doubtless thrown overboard from passing vessels.

FIG. 13.—Local distribution of the bivalve mollusk *Venericardia borealis*. Here it is almost wholly restricted to the colder waters at the outer ends of Vineyard Sound and Buzzards Bay. Its range along our coast extends from the Arctic Ocean to off Cape Hatteras.

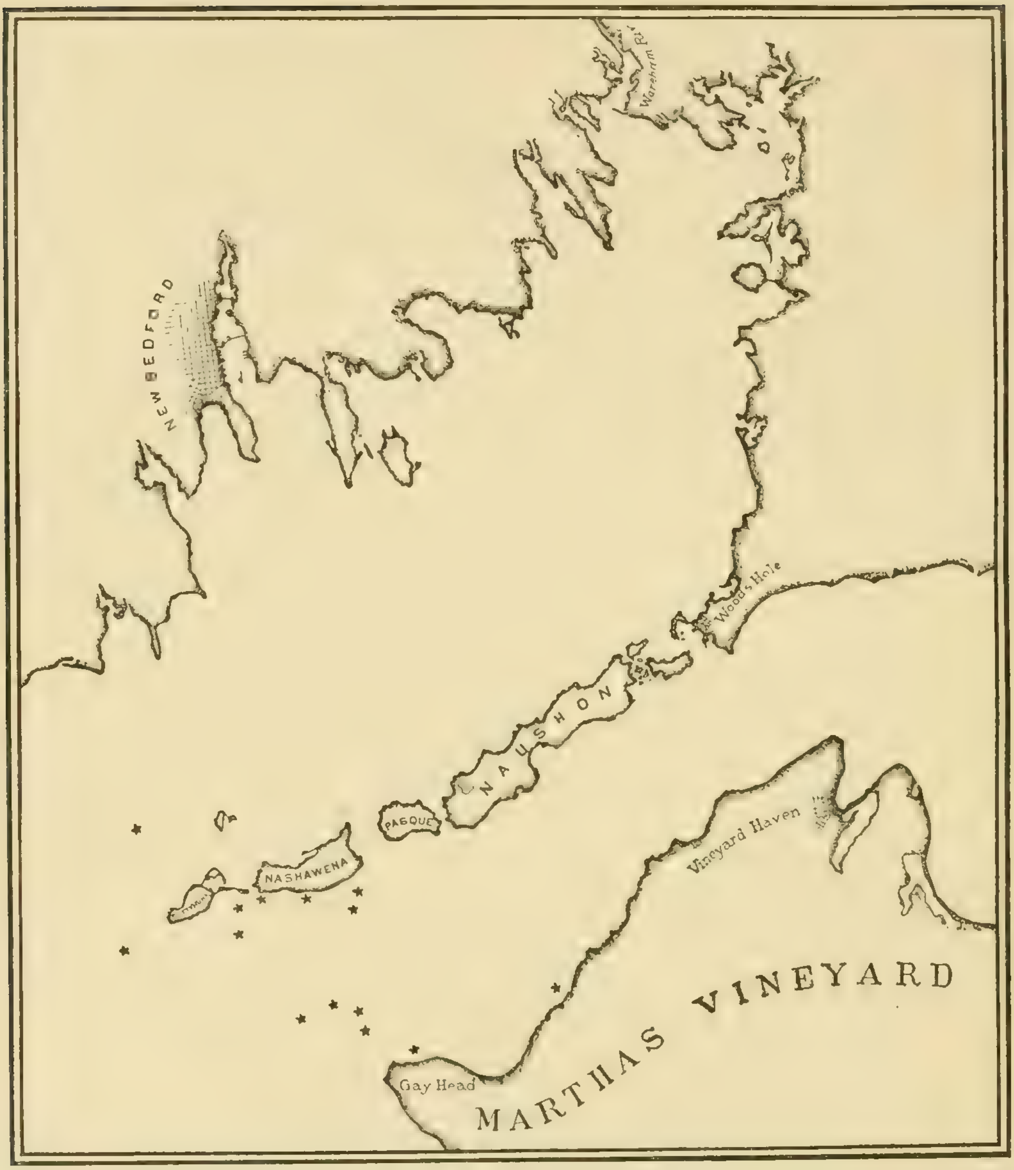


FIG. 14.—Local distribution of the actinian *Alcyonium carneum*, likewise a northern species, ranging from the Gulf of St. Lawrence to Rhode Island.

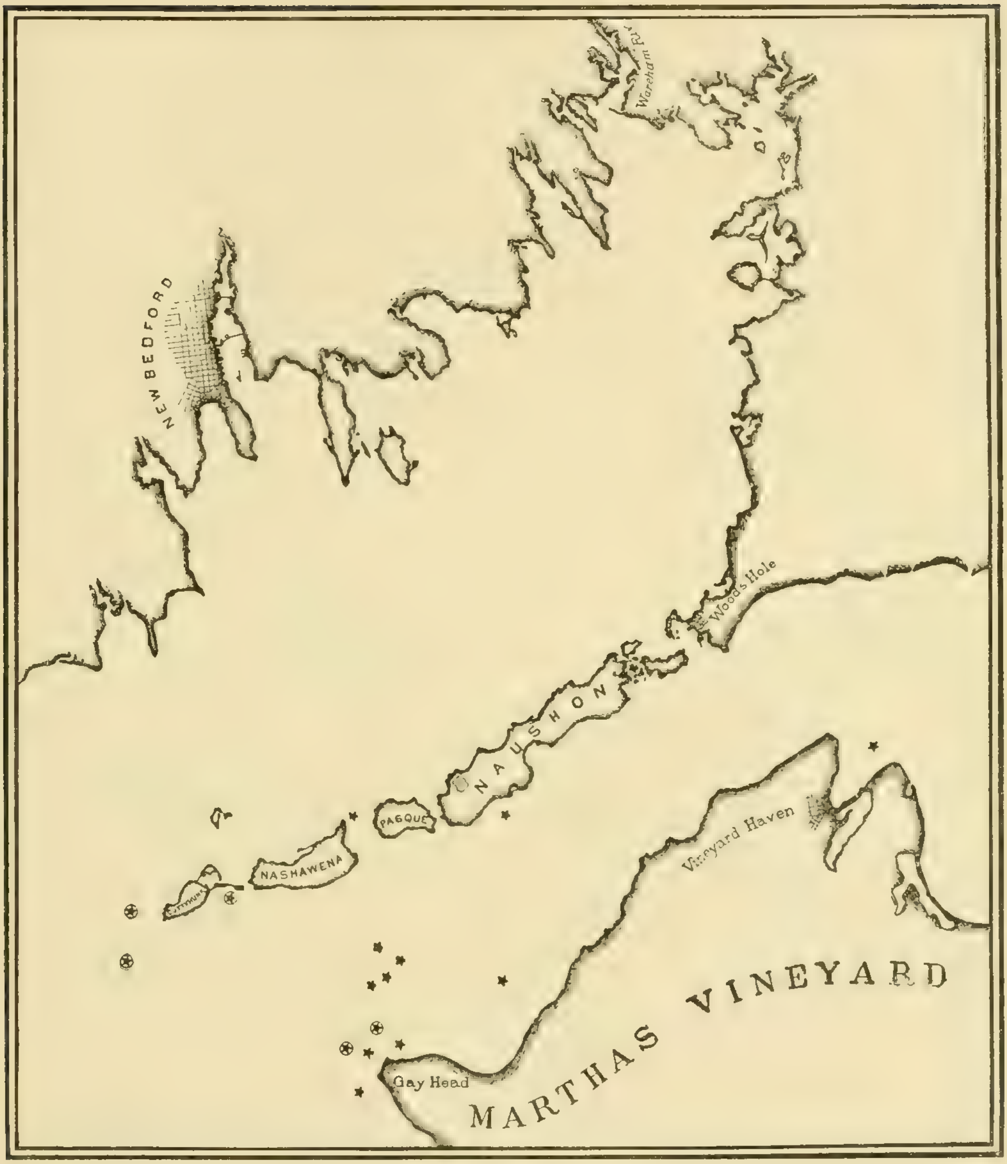


FIG. 15.—Local distribution of the "whelk" *Buccinum undatum*, whose range is from Greenland to "off New Jersey," and perhaps farther south.

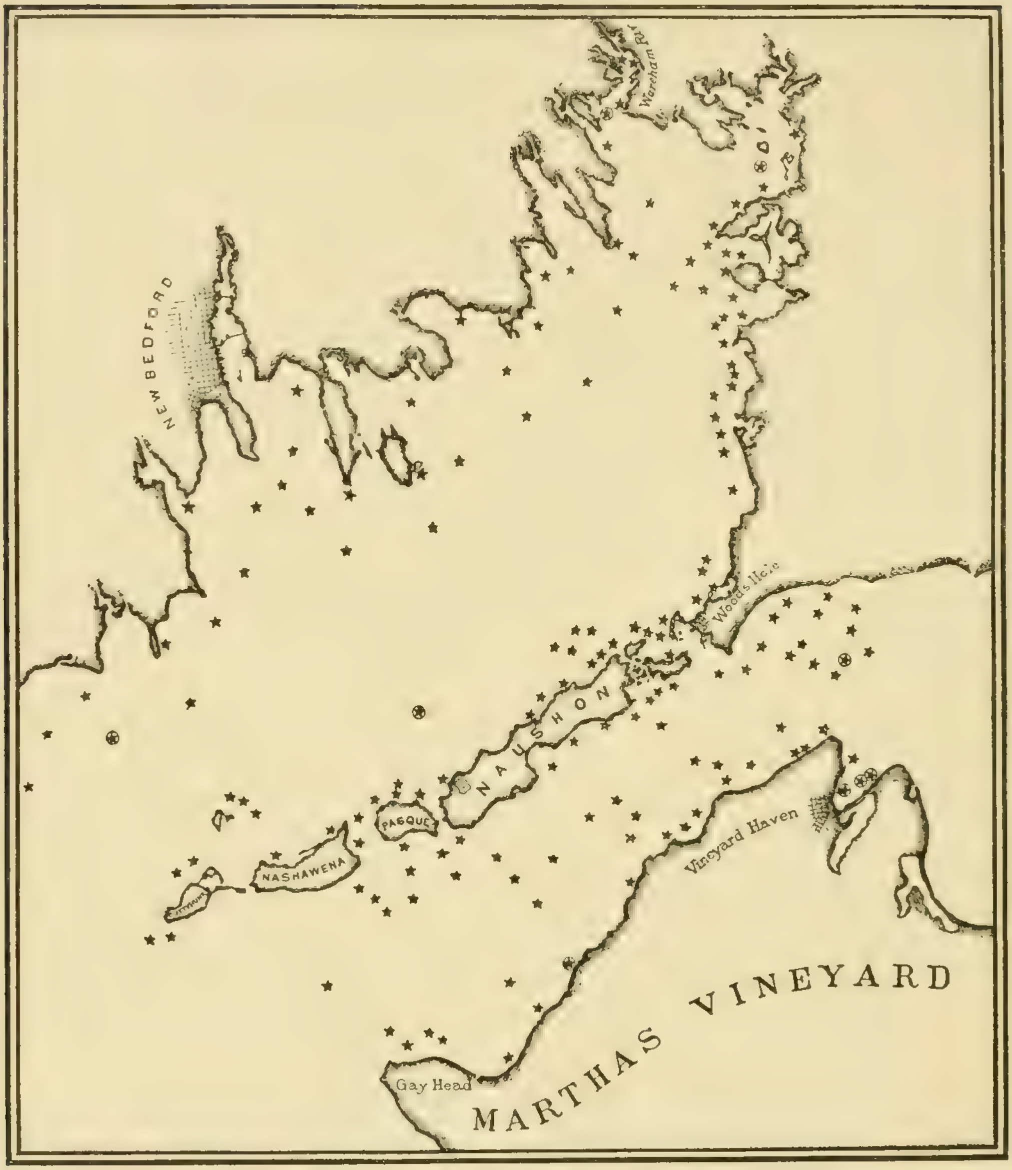


FIG. 16.—Local distribution of the common scallop, *Pecten gibbus borealis*, whose range extends from Nova Scotia to Florida.

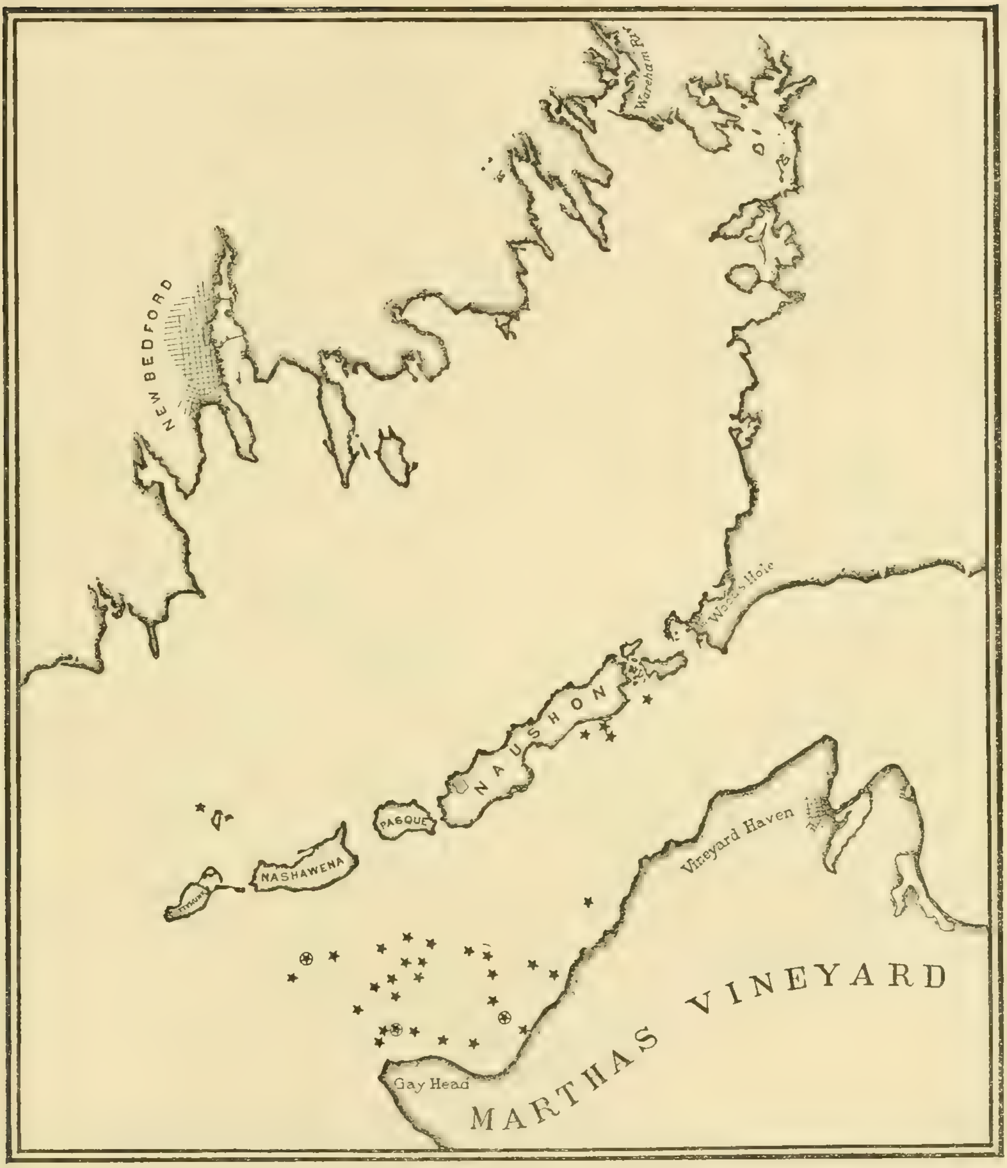


Fig. 17.—Local distribution of the "smooth" or northern scallop, *Pecten magellanicus*, which ranges, on our coast, from Labrador to (off) Cape Hatteras, but which is said to be "rare and local south of Cape Cod." A comparison with the preceding species is significant.

FIG. 18.—Local distribution of the common purple sea-urchin, *Arbacia punctulata*, which ranges from Nantucket Shoals to Yucatan.

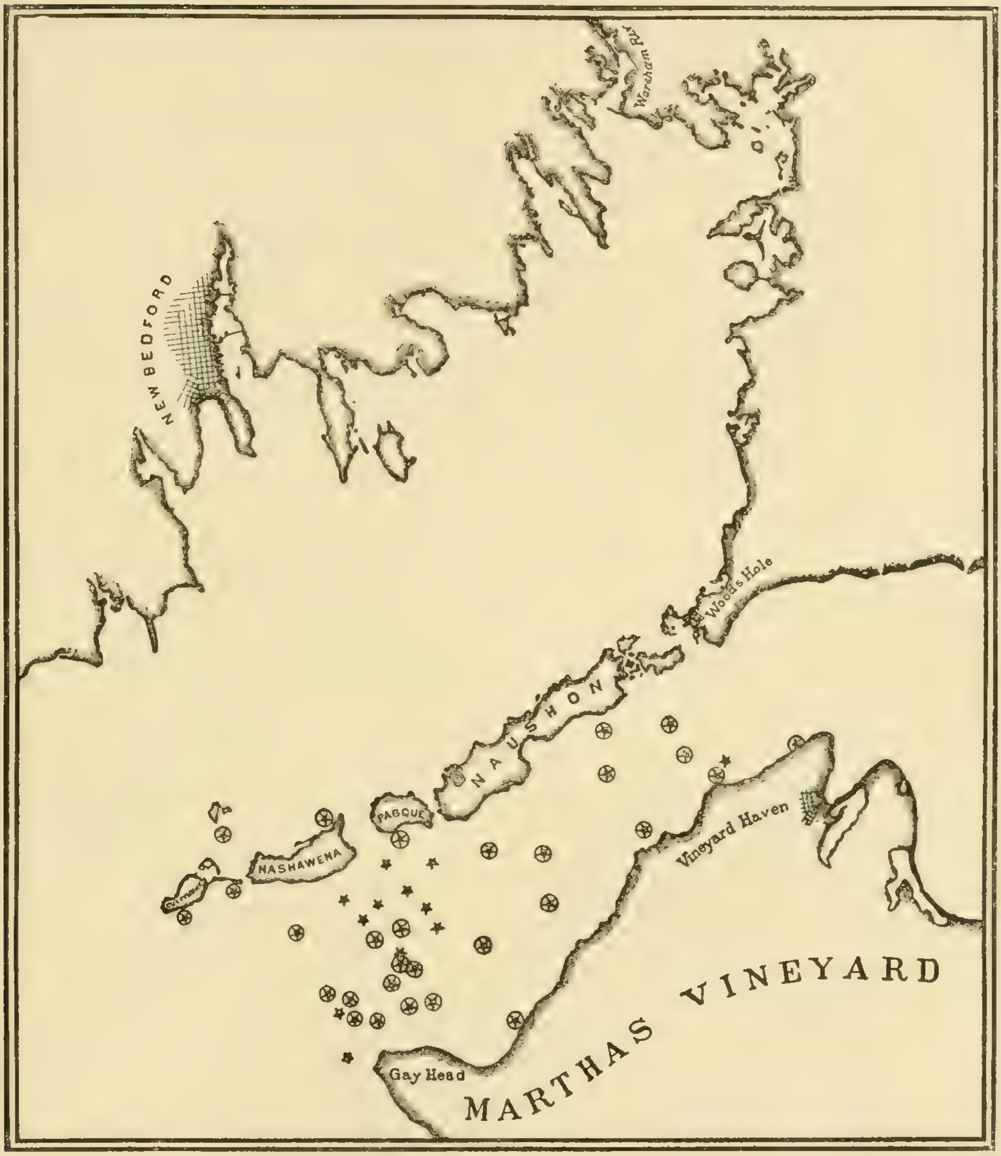


FIG. 19.—Local distribution of the green sea-urchin, *Strongylocentrotus dröbachiensis*, whose range is said to be "circumpolar; southward to New Jersey (not in shallow water south of Cape Cod)." Compare this with the preceding species.

FIG. 20.—Local distribution of the common starfish, *Asterias forbesi*, whose range on our coast is from Maine to the Gulf of Mexico. Distribution in local waters very general as compared with *A. vulgaris*.

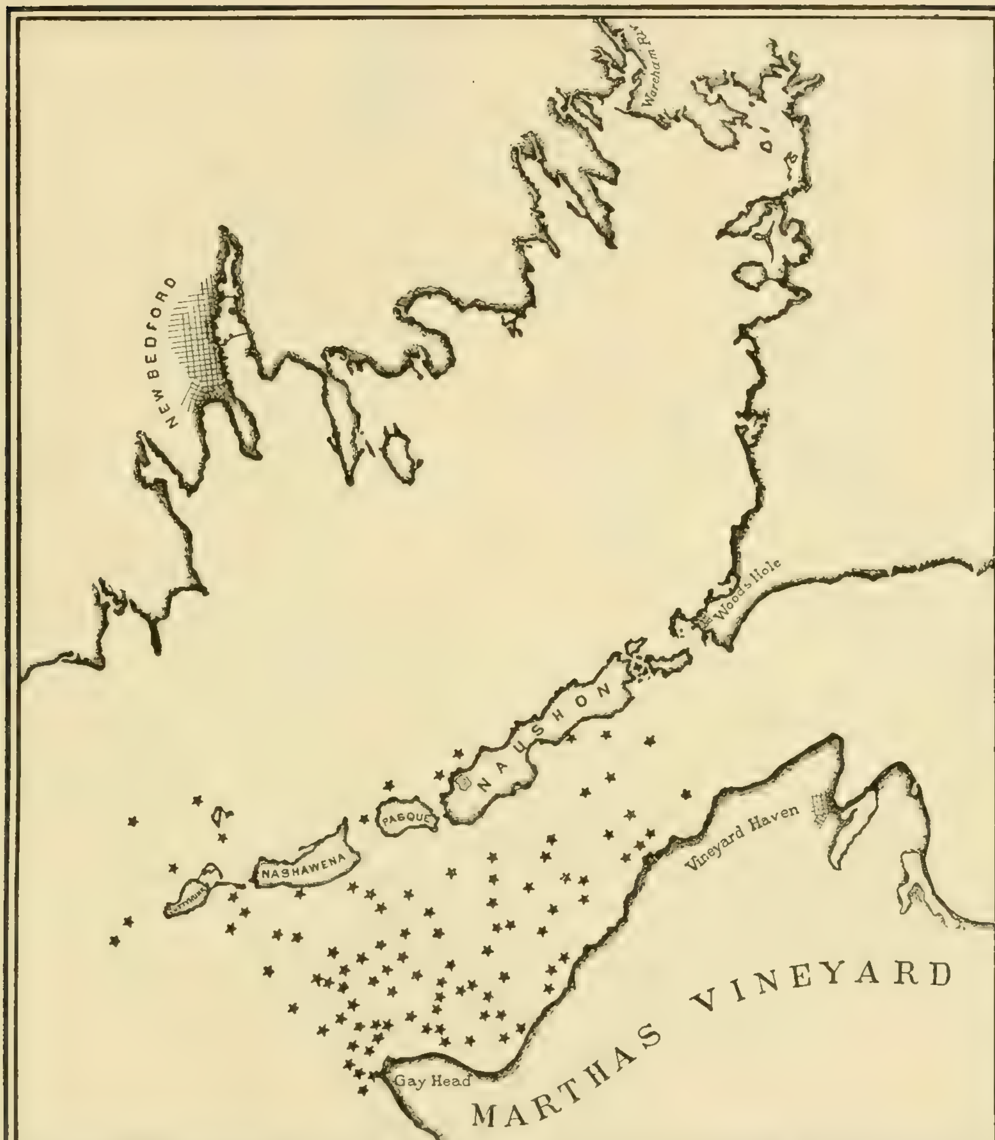


FIG. 21.—Local distribution of the purple starfish, *Asterias vulgaris*, whose range, on our coast, extends from Labrador to Cape Hatteras, it being rarely found in shallow water, however, south of Cape Cod. A concentration in the colder waters is here evident, though the distribution in Vineyard Sound is fairly general.

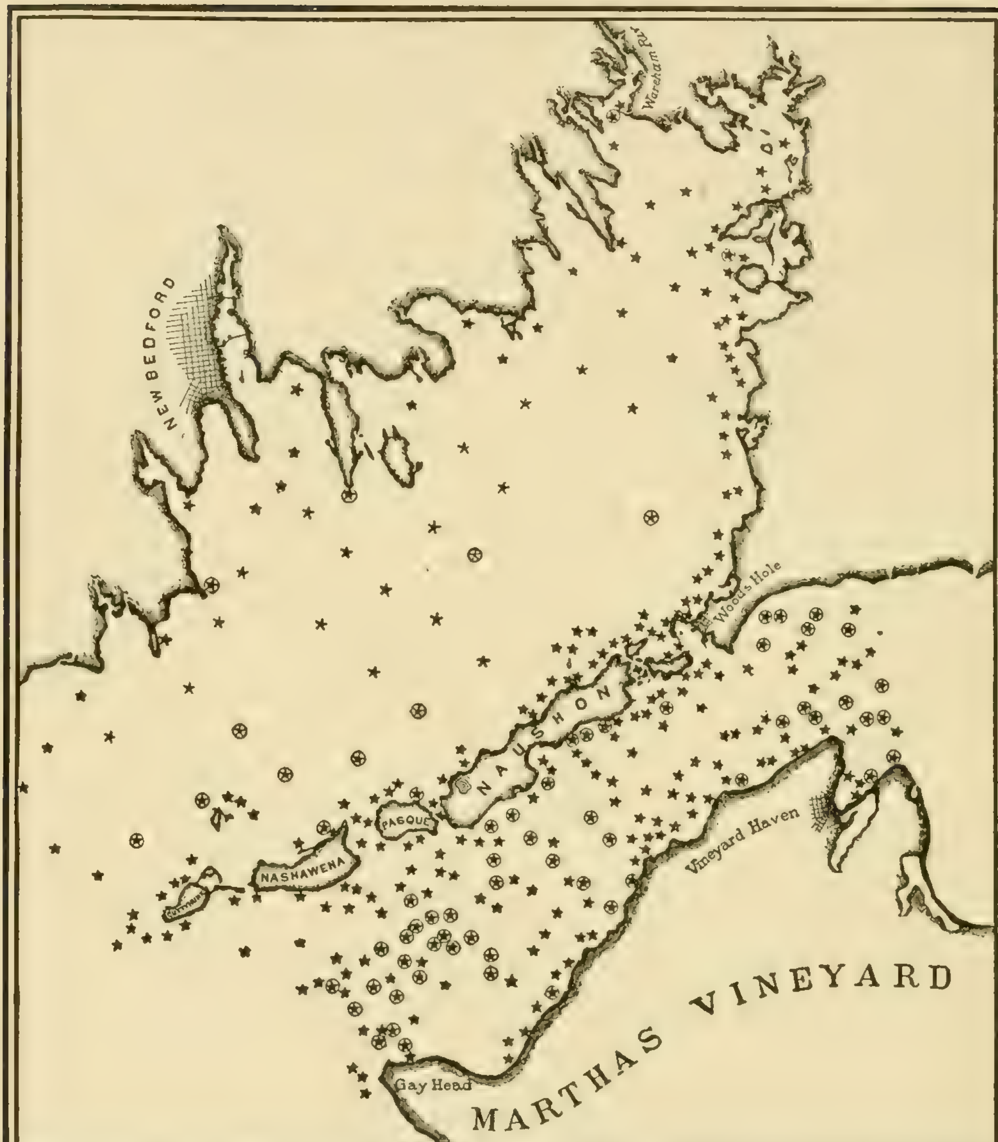


FIG. 22.—Local distribution of the "boat shell," *Crepidula fornicata*. This species is most commonly found upon the shells of the larger hermit crabs, though frequently taken elsewhere. It ranges on our coast from the Gulf of St. Lawrence to the Gulf of Mexico.

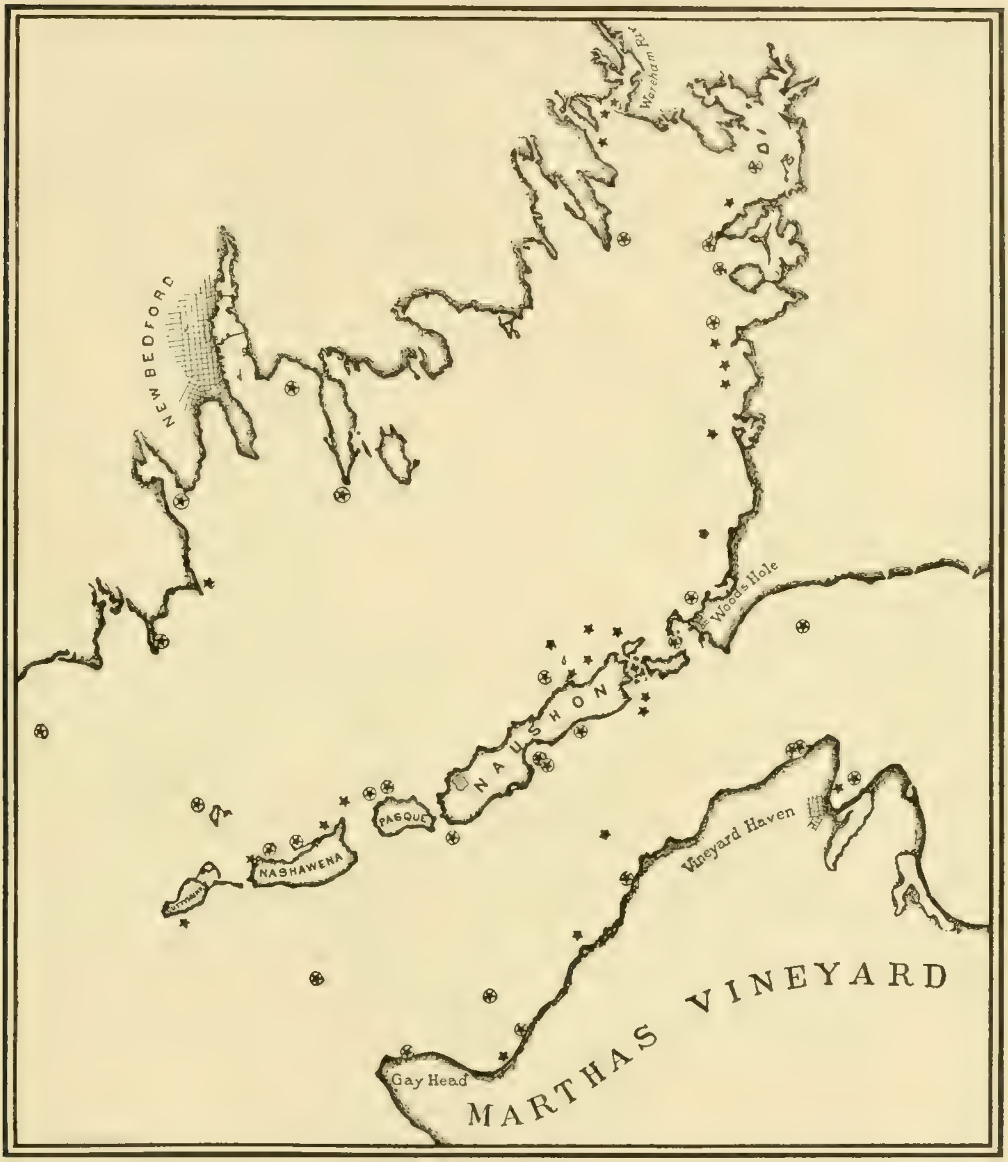


FIG. 23.—Local distribution of *Crepidula convexa*, a smaller species than the preceding. The present species is most frequently taken upon the shells of the small hermit crab, *Pagurus longicarpus*. It is interesting to note, however, that the distribution of the mollusk appears to be almost wholly restricted to the adlittoral zone, while that of the crab is much more general (see fig. 26).

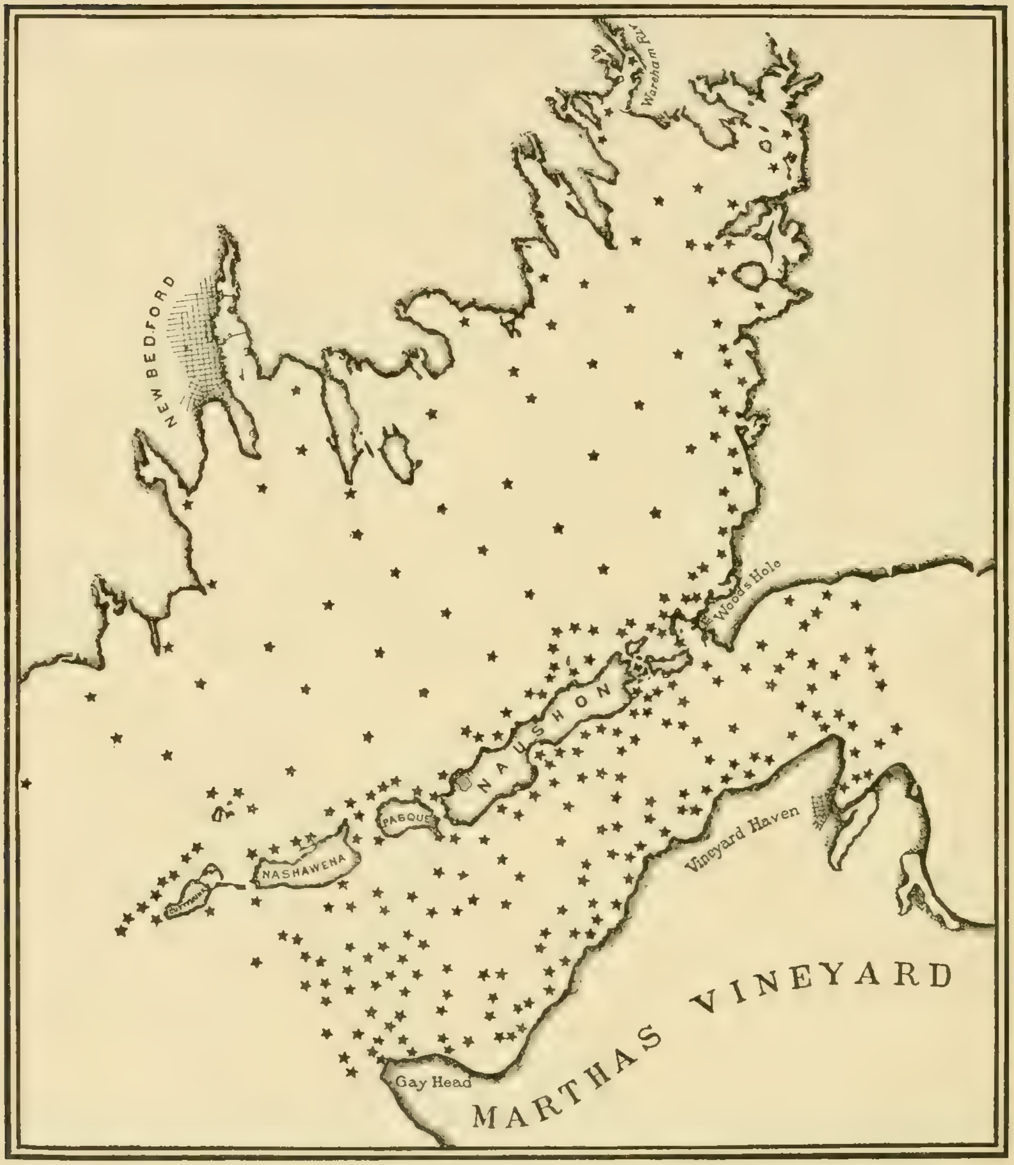


FIG. 24.—Local distribution of the hermit crab *Pagurus longicarpus*, whose range extends from Maine to Texas.

FIG. 25.—Local distribution of the hermit crab *Pagurus pollicaris*, whose range is from Cape Cod Bay to South Carolina.

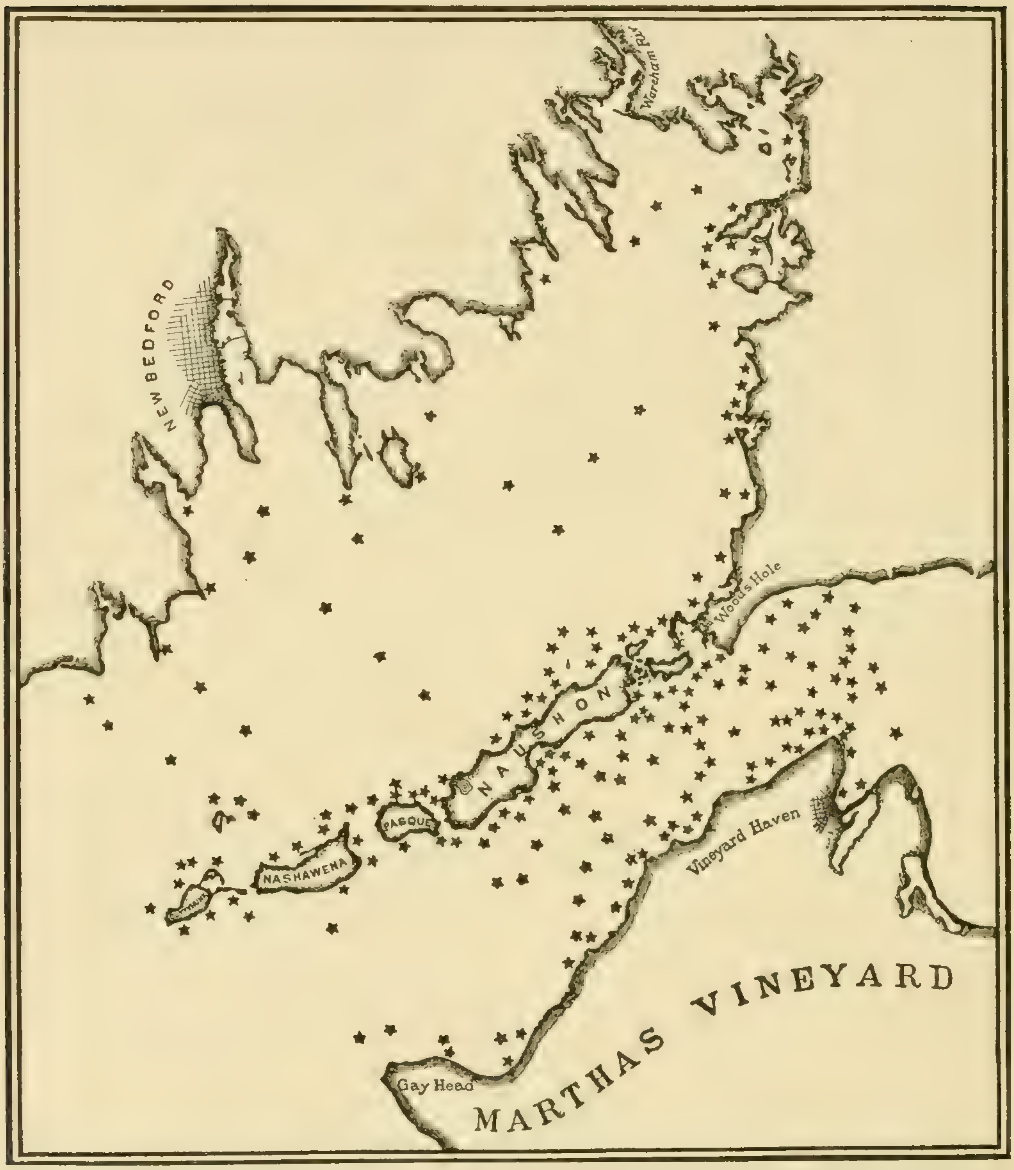


FIG. 26.—Local distribution of the hermit crab *Pagurus annulipes*, whose range is from Nantucket Sound to Florida. Note the absence of this species from the colder waters at the western end of Vineyard Sound, i. e., the very waters to which *P. acadianus* is restricted.

FIG. 27.—Local distribution of the hermit crab *Pagurus acadianus*, whose range is "from the Grand Bank of Newfoundland to the mouth of Chesapeake Bay."

)F THE YEAR, 1902-1

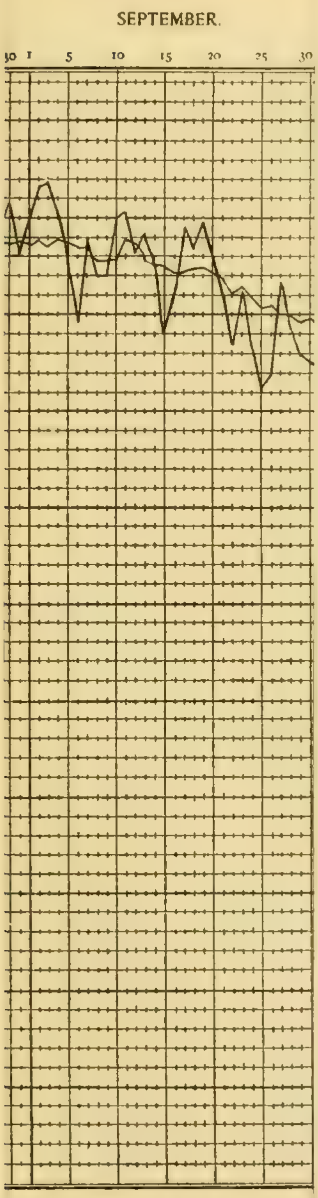
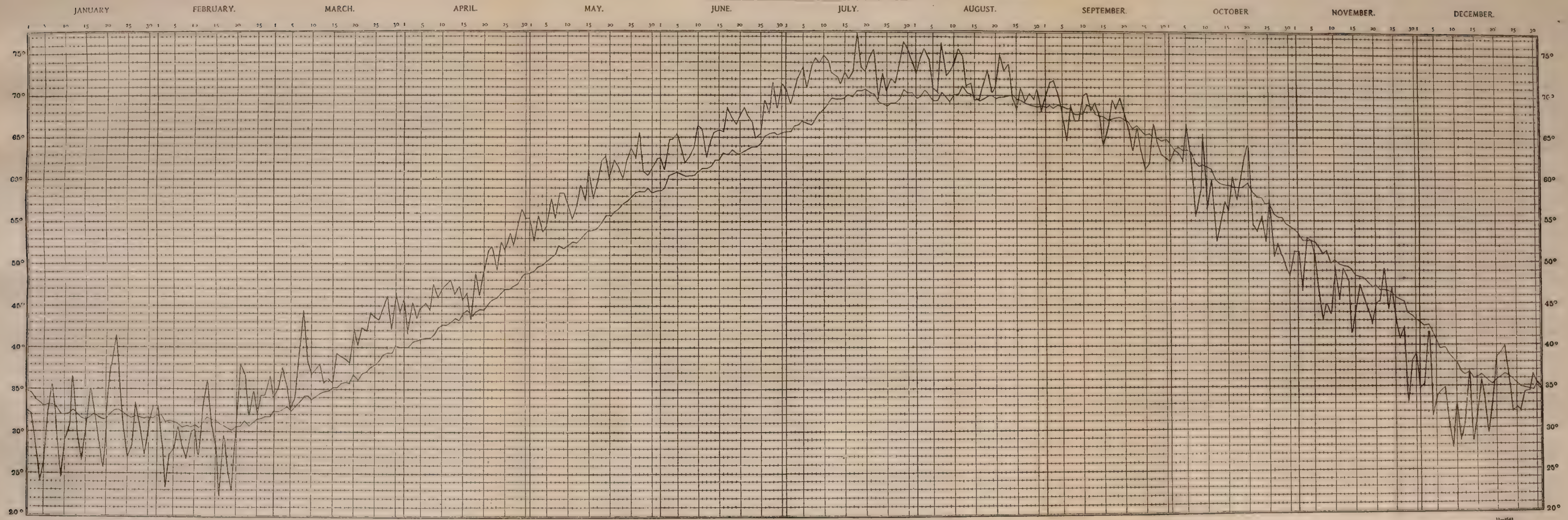


DIAGRAM SHOWING MEAN AIR AND WATER TEMPERATURE AT WOODS HOLE, MASS., FOR EACH DAY OF THE YEAR, 1902-1906, INCLUSIVE.

The less regular line represents Air Temperature, the more regular one, Water Temperature.



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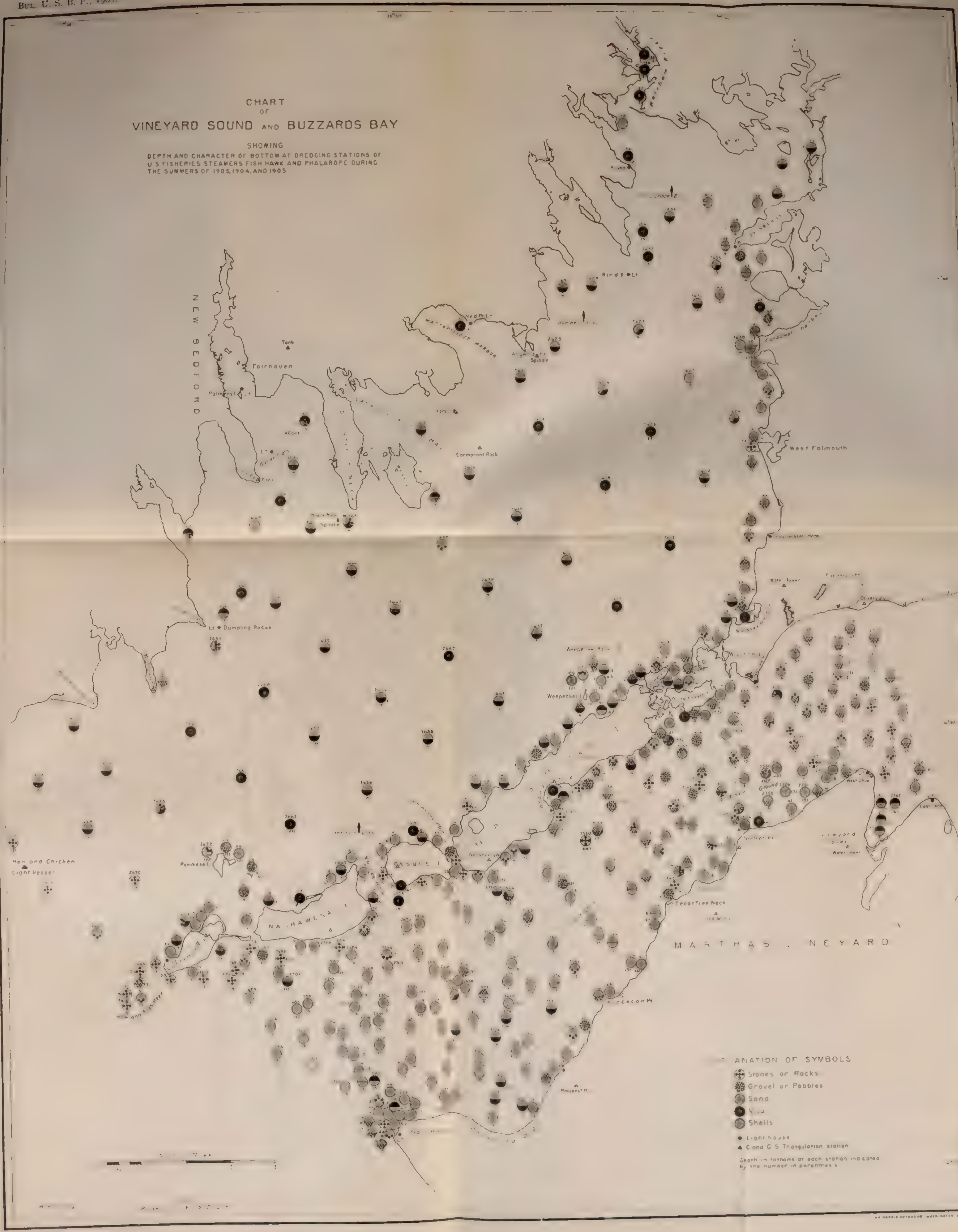
CHART
OF
VINEYARD SOUND AND BUZZARDS BAY
SHOWING
DEPTH AND CHARACTER OF BOTTOM AT DREDGING STATIONS OF
U S FISHERIES STEAMERS FISH HAWK AND PHALAROPE DURING
THE SUMMERS OF 1903, 1904, AND 1905
NEW BEDFORD
Fairhaven
Tank
Bird I Lt
Spindle
Cormorant Rock
West Falmouth
Lt Dumpling Rocks
Weepecket I
Hen and Chicken
Light Vessel
Penikese I.
NASHAWENA I.
Cedar Tree Neck
MARTHAS VINEYARD
Prospect H.
ANATION OF SYMBOLS
Stones or Rocks
Gravel or Pebbles
Sand
Shells
Light house
C and G S Triangulation station

DEVELOPMENT OF SPONGES FROM TISSUE CELLS OUTSIDE THE BODY OF THE PARENT

By H. V. Wilson

Professor of Zoology, University of North Carolina

Paper presented before the Fourth International Fishery Congress
held at Washington, U. S. A., September 22 to 26, 1908

DEVELOPMENT OF SPONGES FROM TISSUE CELLS OUTSIDE THE BODY OF THE PARENT.

By H. V. WILSON,
Professor of Zoology, University of North Carolina.

About five years ago I suggested to the Bureau of Fisheries that an investigation to cover the various ways in which sponges reproduce might yield some results of value for scientific sponge culture. I had in mind the high degree of reproductive (technically, regenerative) power possessed by at least certain body cells, as distinguished from germ cells, in sponges.

This great regenerative power of somatic cells in sponges is displayed, as has long been known, in the formation of asexual masses which under proper conditions develop into new sponges. The regenerative masses of this kind that are best known are the gemmules of fresh-water sponges, but similar gemmules have been discovered by Topsent and others in marine sponges. Observations of my own, dating as far back as 1889,[a] indicated that in some marine sponges such asexual masses not only possess the power to transform into sponges, but in so doing pass through a swimming stage not distinguishable from the ciliated larva which typically develops from an egg. In a case of this kind, as I have pointed out (op. cit., 1891), the nature of the body cell as measured by its potentialities is fundamentally like that of a germ cell—it has full regenerative power, including the ability to recapitulate in some measure the ancestral history of the protoplasm. Considerations of this kind led me to doubt whether in all metazoa the protoplasm really did divide sharply into somatic and germinal cells. Rather was the idea encouraged that in the lower metazoa, such as sponges, the cellular elements all retained just so much of the nature of the germ cell (just so much of the specific idioplasm, one might say) as would enable them, under the influence of an appropriate stimulus, to develop either into ova or sperms, or into asexual reproductive masses. Assuming that sponge protoplasm had this eminently plastic character, I conceived that one might discover ways in which to call into unusual activity the reproductive or regenerative power, and so, as it were, to invent new methods of growing sponges.

[a] Wilson, H. V.: Notes on the development of some sponges, Journal of Morphology, 1891; Observations on the gemmule and egg development of marine sponges, ibid., 1894.

The results, at this time, of the investigation that I have been conducting for the Bureau during the past five summers at the Beaufort laboratory justify, it seems to me, the point of view above outlined. Two new methods by which sponges may be grown have been discovered, and both of these methods attest the remarkable regenerative power of the body cells of sponges. That both methods are applicable to the commercial sponge there can hardly be a doubt. Whether at the present time any economic advantage would accrue from the practice of either is perhaps doubtful, in view of the fact that sponges may so successfully be grown from cuttings—a method first practiced by Oscar Schmidt, and further developed in this country by Richard Rathbun, while in recent years H. F. Moore has brought it through a long series of admirable experiments to a high degree of efficiency.

But while the methods which I shall presently describe may not now be of practical utility, they add something to our knowledge of the underlying scientific principles of sponge culture. And it is a truism that such principles are the funds, so to speak, on which the practice of succeeding generations draws in the conduct of economic enterprises. I am convinced that our knowledge of these scientific principles of sponge culture may be vastly increased. Future researches will surely clear up, among other points, the relation between the formation of sexual products (ova and sperms), of asexual masses which transform directly without passing through the swimming stage (ciliated larva), and of asexual masses which imitate the egg development in passing through the stage of the ciliated larva. I may add that such a relation is "cleared up" to the eye of science (in contradistinction to metaphysics) only after the discovery of the actual treatment to which, when the sponge tissue is subjected, it responds by the development of this or that reproductive body. In this instance, as in many such biological problems, the most intimate knowledge of the structure and movements of the cells concerned in the production of each kind of body is necessary. But such knowledge of itself falls short, and remains unsatisfactory until it leads up through experiment to an actual control of the phenomena—to the power which can at will compel the sponge to produce the one or the other kind of reproductive body.

The first of the two new methods to which I have alluded has been described in Science.[a] It is briefly as follows:

If sponges are kept under appropriate conditions in aquaria, the body dies in some regions, but in localities the cells remain alive and congregate to form masses. In the production of such masses the component cells lose their individuality, fusing with one another to form a continuous mass of protoplasm studded with nuclei (a syncytium). Such masses of syncytial protoplasm are

[a] Wilson, H. V.: A new method by which sponges may be artificially reared. Science, June 7, 1907.

easily seen with the unaided eye scattered through the interior or over the surface of the remains of the original sponge. They are frequently spheroidal, but often of an irregular shape, and have the power of slow amœboid movement. In successful cases of treatment these masses, varying from a fraction of a millimeter to a few millimeters in diameter, are exceedingly abundant. The smaller ones of more regular shape at once call to mind the gemmules that are normally formed in such sponges as *Spongilla*. Experiment shows them to be physiologically like such gemmules in that they have the power to transform into perfect sponges. To bring about this transformation it was only necessary to remove the regenerative masses to the open water of the harbor at Beaufort, where they were kept in small bolting cloth bags suspended in a floating live box. The sponge especially worked on was a silicious form, a species of *Stylotella*.[a]

The second of the two methods, a description of which may be found in the Journal of Experimental Zoology,[b] is the more interesting and important. It should be said that the method succeeds best with sponges in which there is a considerable development of horny skeletal fiber. The form especially used in my work has been *Microciona prolifera* Verrill, and it has proved practically necessary to use always the large bushy specimens. The procedure is as follows:

Cut the sponge into small pieces and put them on a square of bolting cloth. Gather the cloth round the sponge fragments in the shape of a bag. Holding the upper end closed with the fingers, compress the bag repeatedly with small dissecting forceps. The bag meantime remains immersed in a little dish of sea water. The sponge cells are squeezed free of the skeleton and are strained through the pores of the bolting cloth. They fall like a fine sediment on the bottom of the dish. Collect the sediment with a small pipette and strew it over glass plates or shells immersed in sea water. The originally separate cells quickly combine with one another, exhibiting amœboid phenomena. The masses so formed go on fusing with one another through the formation of peripheral pseudopodia, and thus the whole surface of the glass slide (or other object used) may become covered with a network of plasmodial masses and cords, which adhere to it with some firmness. After perhaps half an hour the plate should be lifted from the water and cautiously drained. The sponge plasmodia are thus flattened out somewhat and their attachment to the plate is strengthened. Return the plate at once to a dish of fresh sea water, where it should be left with two or three changes of water for a day. By this time the network of plas-

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[a] Otto Maas has independently discovered that the cells of calcareous sponges under the influence of reagents exhibit a behavior essentially like that above described. See my account in Science, loc. cit.

[b] Wilson, H. V.: On some phenomena of coalescence and regeneration in sponges. Journal of Experimental Zoology, vol. v, no. 2, December, 1907.

modia has probably transformed itself in whole or in great part into a thin uniform incrustation. It is best now to transfer the plate to the open water. My practice has been to tie such plates to the inside of galvanized-wire boxes, and to hang the boxes in a large live-box.

In the course of a week it will be found that the incrustation has transformed itself into a functional sponge with pores, oscula, well-developed canal system, and flagellated chambers. The steps in this gradual differentiation may be followed by examining the sponge at intervals under the microscope. The differentiation goes on, but at a slower rate, in preparations kept continuously in laboratory dishes or aquaria. While the sponge incrustation is quite thin, the currents of water and vibrations of the flagella in the flagellated chambers may be observed with a high power. For this purpose small incrustations grown on cover glasses are the best.

Until the past summer it was a question whether sponges produced in this way would continue to grow and would develop the skeleton characteristic of the species. If they would not, it was clear that the method had no value for economic sponge culture. And so, early in July, I again visited the Beaufort laboratory and with the help of my assistant, Mr. R. R. Bridgers, started some *Microciona* plasmodia on glass slides and oyster shells. It was possible for me to remain at the laboratory only two weeks, but Mr. Bridgers took charge of the sponges and continued to start other plasmodia at intervals during July and August, conducting his experiments with great care and skill.

Mishap of course overtook some of the cultures; but scores of them grew perceptibly during the summer and by the first of September a large number had developed the skeleton of the adult with the characteristic spicules and the horny columns projecting up from the basal skeletal plate. What was equally gratifying was that the sponge in many cases had not only spread and thickened and developed the species-skeleton, but had also developed quantities of reproductive bodies. These lay scattered in the deeper part of the incrustation, plainly visible to the eye. I have not yet made a sufficiently precise histological examination of these bodies to determine whether they are egg larvæ or asexual masses. The whole appearance of the sponges grown in this way, some six weeks old, is quite like that of normal *Microciona* of incrusting habit.

Looking from the utilitarian standpoint at this latter method of growing sponges, it is not at all inconceivable that it may at some time be of direct economic value. The ease with which quantities of sponge cells may be had and the opportunity afforded of attaching them to any desired object are considerations which encourage such an idea. Going farther afield from present-day practice and looking to the future, the method suggests itself as one of the possible means of altering the specific characteristics of sponges and improving races. In

a paper presented to the National Fishery Congress of 1898 [a] I briefly discussed the possibility of improving sponge races, suggesting as means thereto the breeding of sponges from the egg with accompanying selection, and also the practice of grafting. Now if the cells of two closely allied races were mixed together it is on the whole probable that a composite plasmodium would result which would develop the characteristics of both races. Such a form would be something comparable to a hybrid. I have in fact carried on experiments of this character. [b] The results of my experiments were negative—the cells of each species coalesced, but there was no permanent union between the cells or cell masses of the different species. It should be said, however, that the species used were so unlike that there was at the outset but little chance of coalescence. In a more favorable locality, where a great variety of horny sponges exist, such experiments hold forth some promise.

NOTE.—In connection with the foregoing paper there was an exhibit of microphotographs illustrating some of the more important stages in the development of sponges from cells forcibly removed from the parent body.

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[a] Wilson, H. V.: On the feasibility of raising sponges from the egg. Proceedings of the National Fishery Congress, 1898, in U. S. Fish Commission Bulletin, vol. XVII, 1897.

[b] Journal of Experimental Zoology, loc. cit.

GASES DISSOLVED IN THE WATERS OF WISCONSIN LAKES

By Edward A. Birge
Secretary Wisconsin Commission of Fisheries

Paper presented before the Fourth International Fishery Congress
held at Washington, U. S. A., September 22 to 26, 1908

GASES DISSOLVED IN THE WATERS OF WISCONSIN LAKES.

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In the following paper I propose to sketch briefly a small part of the work on lakes which the Wisconsin Geological and Natural History Survey has been carrying on during the past four seasons. During 1907 and 1908 our investigations have been aided by a grant of money from the United States Bureau of Fisheries, which has enabled us to extend our field work much more than would have been possible without this assistance.

LAKE DISTRICTS OF WISCONSIN.

The accompanying sketch map (fig. 1) roughly indicates the position of the lakes that have been studied. Wisconsin contains many hundreds of small lakes, most of them lying in the moraines and found in hollows occasioned by the melting of blocks of ice left during the glacial period. They occur in three pretty well-defined districts, in the southeastern, the northeastern, and the northwestern parts of the state. The water of the lakes in each district, though varying much, shows a very definite general character, especially in the matter of dissolved carbonates.

The southeastern lake district, as studied by us, extends from Waupaca on the north to Lake Geneva on the south, and from the lakes at Madison to Lake Michigan. Nearly 50 lakes in this district have been studied by our survey, and almost without exception they contain considerable quantities of dissolved carbonates, represented by 30 cubic centimeters to 50 cubic centimeters or more of carbon dioxide. Most of the work has been done upon these lakes. Very numerous observations have been made upon Lake Mendota at Madison, the headquarters of the survey, and some hundreds of series of determinations have been made on this lake at all seasons of the year. Much less frequent observations have been made on a dozen or more other lakes in the same region, giving a general picture of the annual cycle of gas changes of these lakes, though not in the same detail as for Lake Mendota.[a]

[a] The diagrams accompanying this paper have been selected from a great number which have resulted from the work of this survey, and are intended to illustrate some points in the distribution of temperature, of the various gases, and of dissolved carbonates of lime and magnesium in the waters of Wisconsin lakes. In all diagrams the vertical spaces represent the depth in meters. The horizontal spaces represent either degrees centigrade in the case of temperature, or cubic centimeters of gas per liter. The line marked "T" indicates the temperature; oxygen is marked "O"; nitrogen, "N"; carbon dioxide, "C"; and carbonates, "Cb." In the diagrams which show nitrogen, both this gas and oxygen were determined by boiling. In those without nitrogen, the oxygen was determined by titrating according to Winkler's method. The alkalinity or acidity of the water were determined by titrating

In the northeastern part of the state is a district somewhat triangular in shape, measuring roughly some 30 miles on each side, and containing several

FIG. 1.—Sketch map of Wisconsin, showing lake districts. Scale about 1 inch=66 miles, or $\frac{1}{4,000,000}$. Green Lake lies directly north of "G". The Oconomowoc district is marked "O". Lake Geneva lies close to the southern boundary. Hammills Lake in northwestern Wisconsin is marked "H".

with standard solutions of HCl or Na_2CO_3, with phenolphthalein as an indicator. The result is expressed in the diagrams in cubic centimeters of CO_2 per liter, acidity being shown as free CO_2, while alkalinity is represented by platting the number of cubic centimeters of CO_2 that would be required to bring about a neutral reaction. Where the line indicating the CO_2 passes to the left of the zero line, it indicates that the water is alkaline.

The amount of dissolved carbonates was determined by titrating with HCl, with methyl orange as an indicator. It is represented in the diagrams by the number of cubic centimeters per liter of CO_2 set

hundred small lakes. About 60 of the more important and deeper lakes in this region have been studied during the summer. The survey has found that the month of August and the early part of September represent the critical period for the distribution of gas in lakes, and that from observations made at this time the general history of a lake may be inferred when the cycle is known in detail from a number of lakes which may serve as standards. The lakes of northeastern Wisconsin contain, in general, soft water, the carbonates being much lower than in the southeastern lakes—frequently not more than one-sixth as great and not infrequently less than one-tenth.

The lakes in the northwestern district are scattered in two somewhat ill-defined elongated series extending north and south for a distance of 70 miles or more. Between 50 and 60 of these lakes also have been examined. Their water is intermediate in character between that of the two other districts, the content in carbonates averaging nearly one-half as great as that of the southeastern lakes.

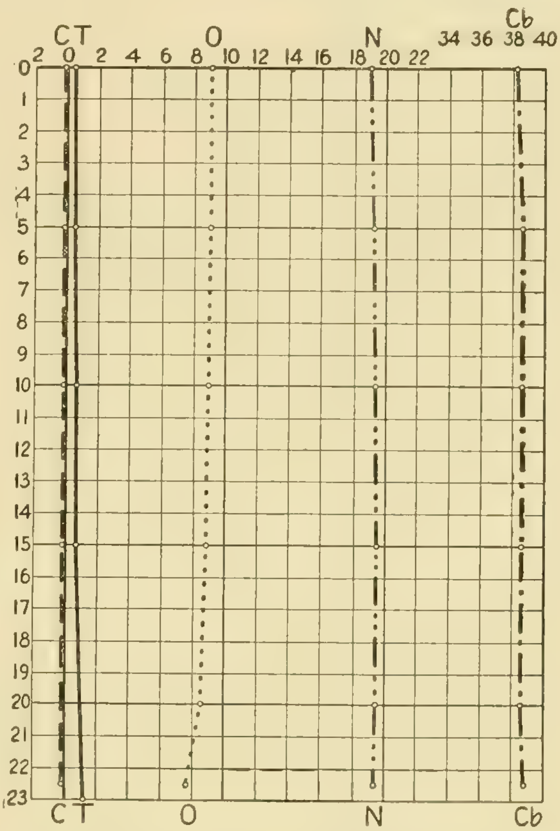


Fig. 2.—Lake Mendota. Vertical distribution of gases, carbonates, and temperature, January 26, 1906. C, carbon dioxide; Cb, carbonates of lime and magnesia; N, nitrogen; O, oxygen; T, temperature. See footnote.

GASEOUS CHANGES IN LAKE MENDOTA.

WINTER.

Let me begin my account by a short sketch of the cycle of changes in Lake Mendota. Figure 2 shows the condition under the ice in early winter. The

free from the monocarbonates. Since, in the lakes of southeastern Wisconsin, the amount of dissolved carbonates is considerable, the numeration of the horizontal scale is interrupted in order not to make the diagram too large. For instance, the numbers at the top of figure 2 change abruptly from 22 to 34. The larger numbers refer solely to the line Cb, indicating the number of cubic centimeters of CO_2 represented in the monocarbonates. A similar arrangement will be seen in other diagrams.

The points at which observations were taken are indicated by small circles in the lines of the diagrams. The lines are drawn directly from one point of observation to the next, no attempt being made to round off the curves.

temperature is nearly the same at all depths, rising from less than one degree just below the ice to something over one degree at the bottom. The water contains about 9 cubic centimeters of oxygen per liter, except in the bottom, where it has begun to disappear under the action of decomposition. Nitrogen is present to about the amount required to saturate water at the given temperature. The reaction of the water is neutral or slightly alkaline at all depths. Carbonates are present to an amount represented by about 38 cubic centimeters of carbon dioxide per liter.

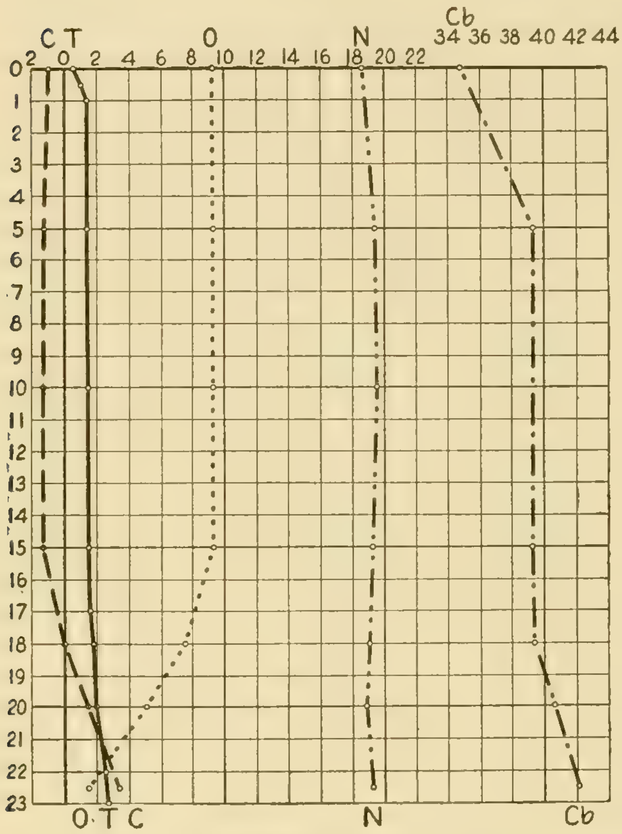


FIG. 3.—Lake Mendota, February 25, 1906.

As the winter advances (fig. 3) some changes occur under the ice. The temperature rises slowly at all depths, but most rapidly at the bottom. Slow decomposition goes on in the deeper water, where also the greater part of the fish are found. There thus results a reduction of the amount of oxygen, which may nearly or quite disappear at the bottom, and a corresponding development of carbon dioxide, so that as winter advances the bottom water may contain considerable quantities of free carbon dioxide. The reaction of the upper water becomes much more markedly alkaline than in the early winter, a change probably due to the influence of the growing plants. The carbonates may or may not decrease in the water immediately below the ice. If a diminution is found (and such decrease may be very pronounced, as in fig. 4), the change is due to the accumulation beneath the ice of water resulting from the melting of the ice or snow and containing, therefore, less dissolved matter than the water of the lake usually holds. As the season advances a rapid growth of algæ may take place beneath the ice, resulting in a considerable increase of the oxygen, which may carry it beyond the point of saturation. This increase is usually accompanied by a considerable increase in the alkalinity of the water (fig. 4).

SPRING AND SUMMER.

When the ice has disappeared in the spring (fig. 5), the water is once more mixed throughout the entire depth, and uniform conditions are again established. The reaction becomes almost or quite neutral. Oxygen is present to about the point of saturation, although, in figure 5, some trace of the winter's diminution of oxygen is still present at the bottom. Carbonates and nitrogen are distributed about uniformly at all depths. As the spring advances and the algæ begin their spring growth, the reaction of the water becomes increasingly

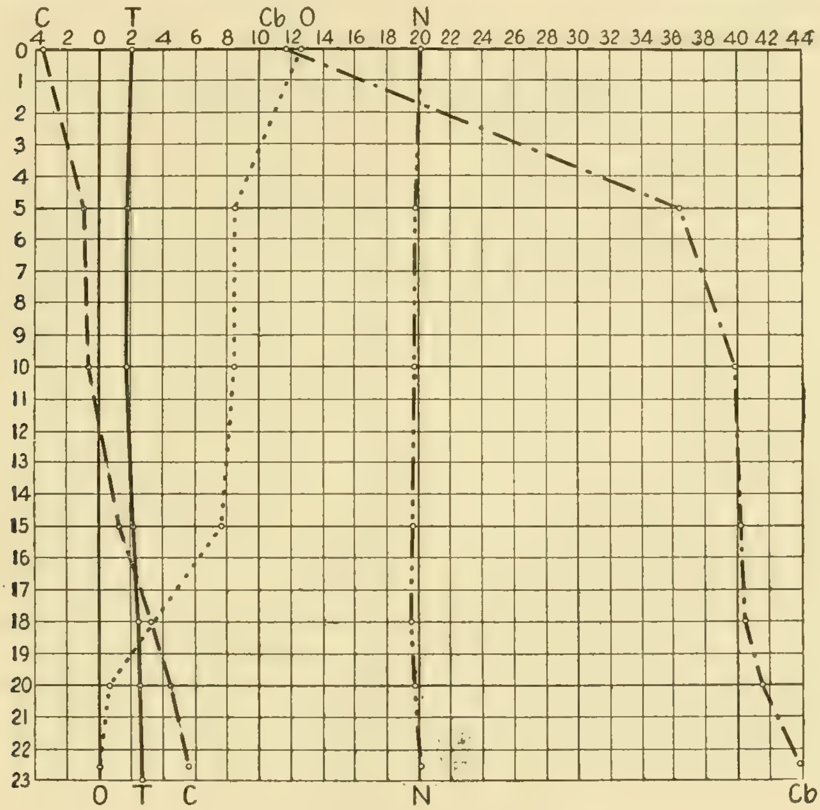


Fig. 4.—Lake Mendota, March 29, 1906.

alkaline. (Fig. 6.) The temperature rises, and soon the surface gains so rapidly in warmth that the wind is unable to distribute the surface water throughout all depths; the circulation becomes increasingly restricted, and summer conditions begin to develop. The temperature curve (fig. 7) shows a marked difference between surface and bottom temperatures, and indicates a temporary thermocline at the depth of 10 meters or more. Corresponding to this stratification of the water and consequent shutting off of the lower water with direct contact with the air, the oxygen in the lower water begins to decline

and free carbon dioxide begins to appear there. This process is accentuated as summer approaches. (Fig. 7 and 8.) The amount of free carbon dioxide increases, the thickness of the stratum of the water whose reaction is acid increases also, and the oxygen steadily and rapidly declines in the lower water. By the early part of July the permanent summer conditions of temperature are found. (Fig. 8.) The regular summer thermocline is found lying, in general, between 5 meters and 10 meters. Oxygen has disappeared wholly from the bottom waters, and is rapidly going from all parts of the lake below the thermocline. The water has divided into an upper warm stratum containing an abundance of oxygen and with an alkaline reaction, and a lower, colder layer with free carbon dioxide, and little or no oxygen except in the extreme upper part.

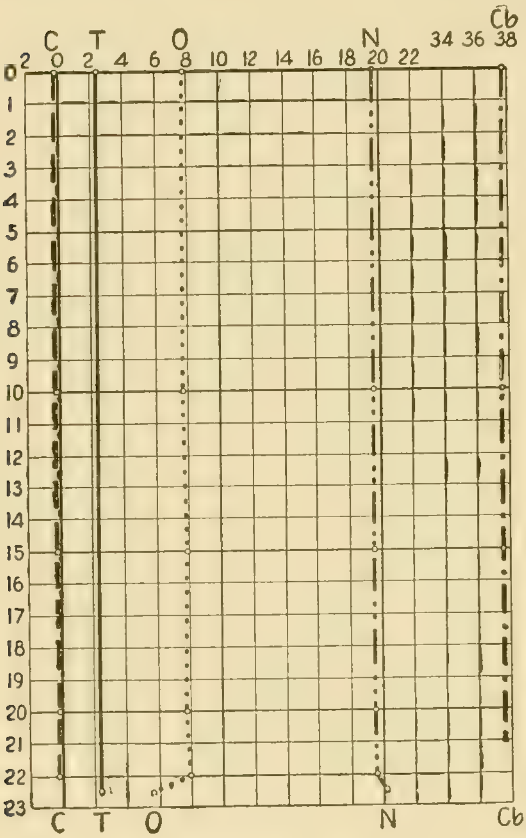


FIG. 5.—Lake Mendota, April 8, 1906.

LATE SUMMER AND AUTUMN.

By the first of August this condition has reached its maximum. (Fig. 9). The lake contains no oxygen below a depth of 10 meters. Above that level, in the warm water and in the uppermost part of the thermocline, there is abundance of oxygen for animal life. Beneath that depth no active animal life is found in the water,[a] though the inhabitants of the mud remain alive through this period, some of them in an inactive condition and some in a partially active state. The carbonates show the characteristic summer condition, in which the upper water contains a smaller amount than the lower, the transition coming in rapidly at the thermocline. This condition persists through August and early September for a period varying with the warmth of the season. As the temperature of the water begins to fall, the thermocline moves downward under the action of the wind, and this process increases the extent of circulating water and in like degree the thickness of the layer containing oxygen. Figure 10 illustrates this condition in early October. The cold weather and winds which are apt to occur at about this time soon bring about a complete mixture of the

[a] Except *Corethra* larvæ, whose presence is an apparent rather than a real exception.

water (fig. 11); and with it returns the condition of uniformity which we found at the opening of winter. From this time until the lake freezes the temperature declines almost uniformly at all depths; the amount of oxygen increases as the capacity of the water to hold it rises with the fall in temperature; and the water becomes almost or quite neutral as the vigor of the growing algæ declines and as decomposition becomes slower in the cooling water.

From this brief account it is plain that the cycle of gas changes in Lake Mendota is a very important factor in determining the conditions and possibilities of life in that lake. Here is an inland lake, one of the largest in Wisconsin,

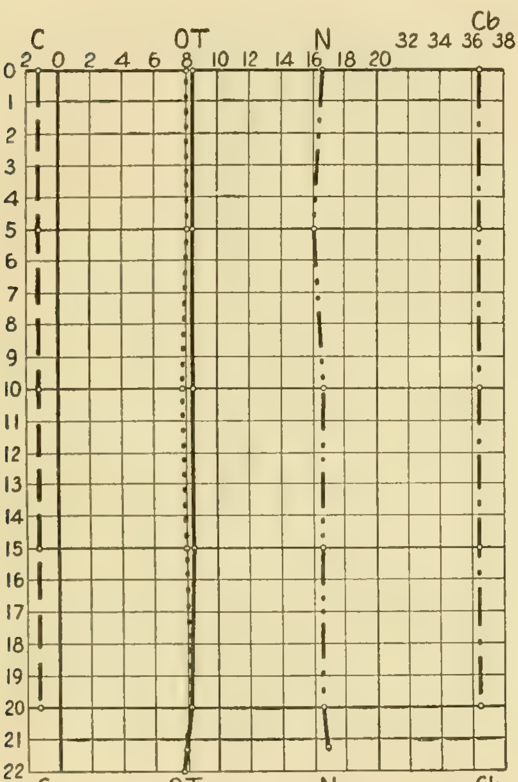


Fig. 6.—Lake Mendota, May 4, 1906.

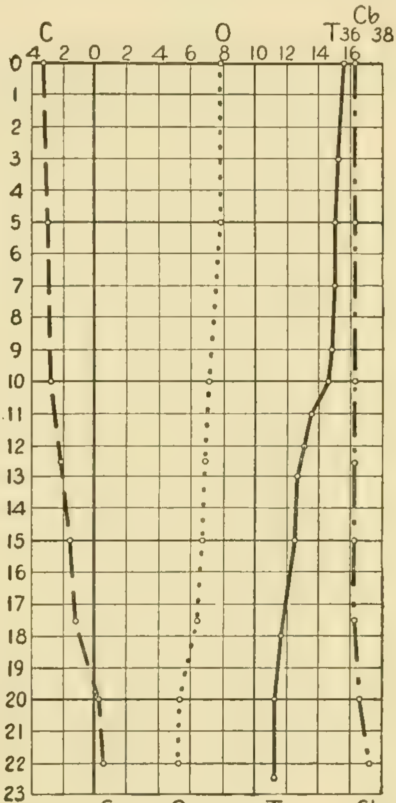


Fig. 7.—Lake Mendota, May 22, 1906.

about 9 kilometers in length and 6 kilometers in breadth, with a maximum depth of 24 meters and an average depth of about 12 meters, the lower half of whose water is wholly uninhabitable during middle and late summer and early fall. This water in the early spring is saturated with oxygen, as is the lower water of all lakes, but the supply is not great enough to meet the demands which are made upon it. The lake is peculiarly rich in plankton, and the decomposition of the great amount of animal and vegetable débris which is showered down from the upper waters into the lower soon exhausts the oxygen supply and renders the lower water unfit for the maintenance of higher life.

Thus the vital conditions in one part of the lake very sharply limit the possibilities of life in another portion. None of those fish which demand a refuge in the cold bottom water during the summer can live in Lake Mendota, nor is it possible to find there those members of the plankton which belong only in the deeper and colder water.

It is perhaps unfortunate for some reasons that Lake Mendota was necessarily the lake on which the most numerous observations were made, since this lake offers an extreme case in the matter of loss of oxygen from the lower water. The oxygen disappears more quickly and fully than in any other Wisconsin lake

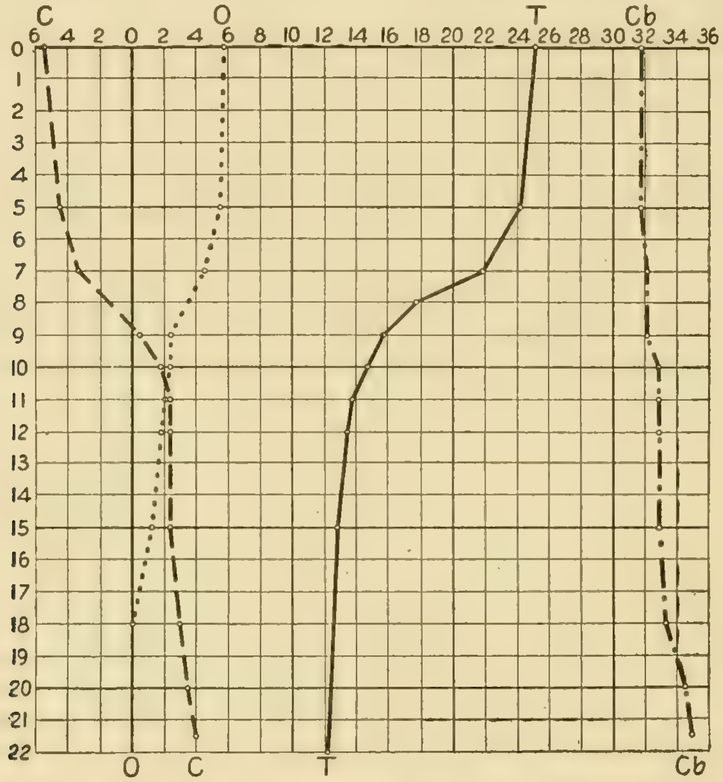


FIG. 8.—Lake Mendota, July 2, 1906.

of approximately equal size and depth. The area of the lake is so large that the bottom water has necessarily a relatively high temperature, and the plankton is so abundant that the lower water is continually receiving great quantities of decomposable matter. Moreover, the thermocline lies comparatively deep because of the large size of the lake, so that the volume of the cooler water is correspondingly reduced. All of these causes combine to make the disappearance of the oxygen very complete and unusually rapid. This lake therefore affords less opportunity than do other bodies of water for the study of the process in its details.

GASES AND CARBONATES OF OTHER LAKES IN SOUTHEASTERN WISCONSIN.

We may contrast the summer conditions in Lake Mendota with those that obtain in the deepest inland body of water in Wisconsin, Green Lake. This has a maximum depth of 72 meters, with length of about 12 kilometers and a breadth of 4 kilometers. Figure 12 shows the conditions found in Green Lake on October 4, 1906. The volume of water is so great that summer conditions of temperature still remain, and cooling has proceeded to no great depth. The water shows the characteristic summer condition of an alkaline upper stratum,

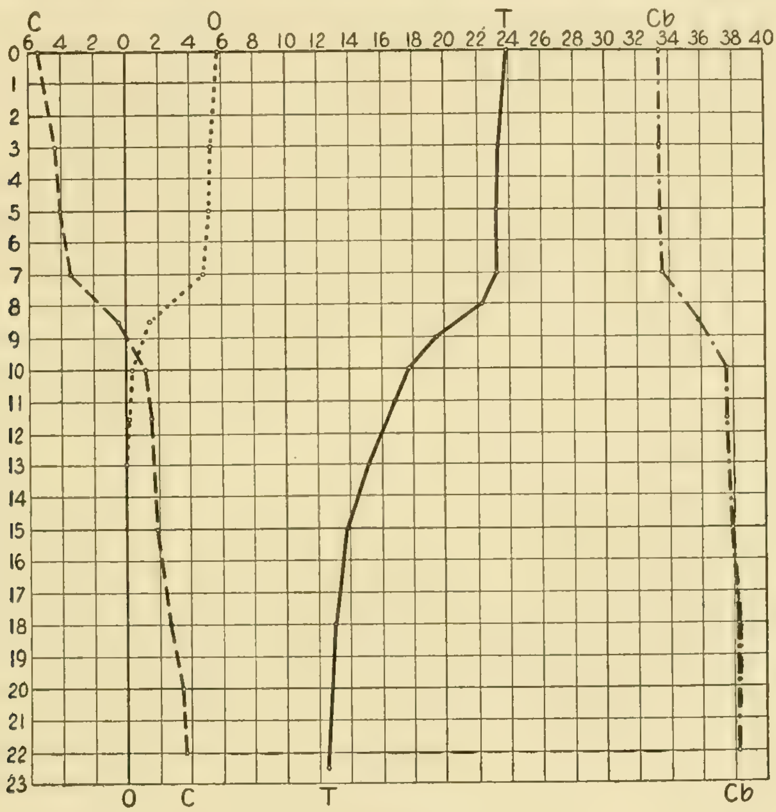


FIG. 9.—Lake Mendota, August 1, 1906.

with the cooler water acid. The dissolved carbonates are low in the warmer waters, rapidly increasing at the thermocline, and then remaining nearly constant till the bottom of the lake is almost reached, where there is again an increase. The oxygen shows a marked diminution in the thermocline (11 meters to 16 meters); it then slowly increases in quantity with the depth until a maximum is reached at about 40 meters, which remains for some 10 meters; and the amount of the gas then declines until it is nearly or quite exhausted at the bottom. The diagram shows plainly the effect of life and death on the oxygen where it is found in abundance in a large volume of water. The oxygen

curve shows that two of the regions where chemical action is going on most vigorously are the thermocline and the bottom water. The accumulation and decomposition of the plankton in the lower water is a sufficient explanation for the changes which take place there. The reduction at the thermocline is apparently due to the fact that the algæ, as they begin to die and sink, often remain for some time at the thermocline. The cool water apparently causes their life to be prolonged, and while certain parts of the filaments are dead and decomposing, others still retain sufficient vitality to keep the plant from sinking. When this period is passed, the plant sinks steadily and rather rapidly to the bottom, thus consuming comparatively little oxygen on the journey. Many forms of plankton animals also accumulate in the thermocline, finding there more food than in any other part of the cool water. Both these causes, then, lead to a diminution of the oxygen at this point. It must not be supposed that there has been no loss of oxygen in the lower water where it is at a maximum. In early spring this water would have contained between 8 cubic centimeters and 9 cubic centimeters per liter, so that at least one-third of the original stock has been consumed.

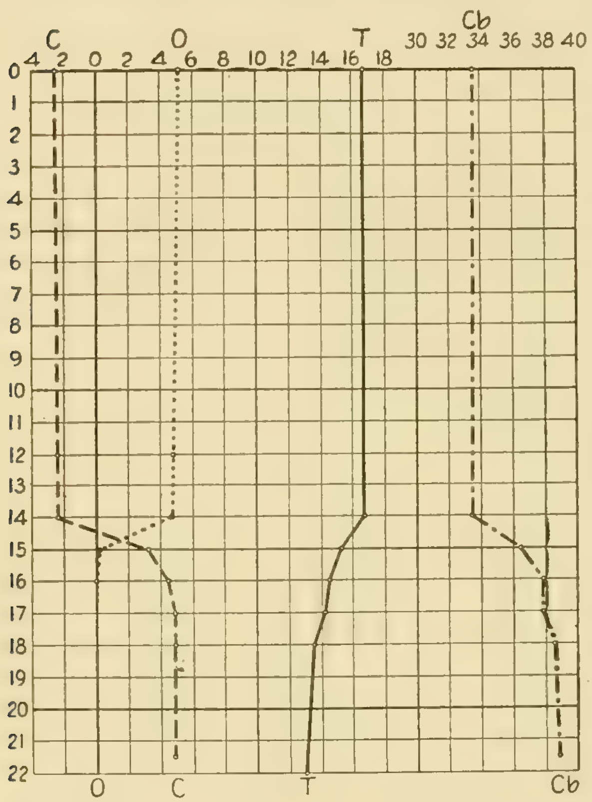


Fig. 10.—Lake Mendota, October 8, 1906.

Green Lake is the only lake in Wisconsin that shows so small a reduction of the oxygen of the lower water. Lake Geneva, near the southern boundary of the state, has about the same dimensions as Green Lake; it is the second deepest lake in the State, having a depth of 41 meters. The late summer conditions are shown in figure 13, where the same general facts are visible as in Green Lake; but the oxygen is much more reduced and shows only a trace, or is altogether absent, from the depth of 33 meters to the bottom. In North Lake, one of the Oconomowoc group, consumption of oxygen at the thermocline goes on more rapidly, and sometimes leads, as is shown in figure 14, to the disappearance of the oxygen from that stratum, while some of the gas still remains at a greater depth.

This lake has an area of about 51 hectares (126 acres) and a depth of about 22 meters. It contains an abundance of oxygen in the water above the thermocline; then follows a stratum in which the gas has almost or quite disappeared; then comes one containing a small amount, but sufficient for the maintenance of a large number of plankton animals; and beneath this to the bottom the water contains no oxygen. A little later, in September, all of the oxygen will have disappeared from the lower water, and the region beneath the thermocline will become uninhabitable by animal life.

LAKES OF NORTHEASTERN WISCONSIN.

All of these illustrations are taken from the lakes of southeastern Wisconsin, where, as shown by the diagrams, the dissolved carbonates are present in large quantities, and where the plankton life is correspondingly abundant. In the lakes of northeastern Wisconsin, where the carbonates are low, the average quantity of plankton is much less than in the hard-water lakes. It is not true that the plankton of every soft-water lake is smaller than that of every hard-water lake. The lakes of both types differ among themselves very greatly, but on the average the statement is entirely correct. European observers have found the same thing for the fish in the lakes of Switzerland that we have found for the plankton in Wisconsin. We have also found that there are fewer fish in the northern lakes than in the southern, hard-water lakes. In these northern lakes, therefore, with their poorer plankton, the oxygen persists longer than in the southern ones. It may disappear entirely, but it usually lingers late, and in the deeper lakes it is apt to remain throughout the season.

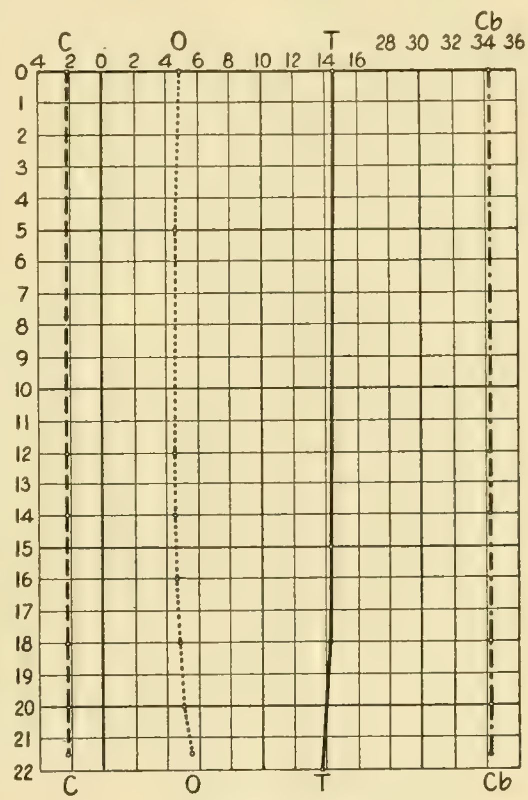


FIG. 11.—Lake Mendota, October 11, 1906.

The diagrams of Thousand Island Lake and Stone Lake (fig. 15, 16) show the summer condition in two of the larger and deeper lakes of this type. The carbonates in both are low, representing about 9 centimeters and 3 cubic centimeters of carbon dioxide, respectively. The upper water is acid, or nearly neutral, the acidity increasing below the thermocline. The oxygen curve of Thousand Island Lake closely resembles that of Green Lake, having a depression

at the thermocline, and an increase in the deeper waters, followed by a gradual decrease to the bottom, where the oxygen is nearly or quite exhausted. This Thousand Island Lake is one of the lakes in northeastern Wisconsin that contain lake trout (*Cristivomer namaycush*). The fish inhabits the bottom water during the summer, and seems to be found native only in lakes which carry an abundance of oxygen to the bottom. The oxygen curve of Stone Lake (fig. 16) shows another interesting fact which is observable in many inland lakes, namely, an increase of oxygen in the upper part of the thermocline. This is due to the presence of algæ at this depth, which still receive sufficient light to manufacture starch, and liberate oxygen in that process. This phenomenon is very commonly found in our lakes, but by no means universally. The crops of algæ, which produce oxygen, are not necessarily continuous; nor is oxygen produced in quantities beyond consumption at all periods of their growth. The thermocline may lie so deep or the water may be so opaque that algæ in the cool water do not get light enough to enable them to produce starch. Neighboring lakes, therefore, which seem quite similar, may or may not show this rise of the oxygen. In the same lake it may appear and disappear during the season, and although usually present at a corresponding time in successive seasons may vary greatly in amount. One common result of this process is the using up, at this point, of the carbon

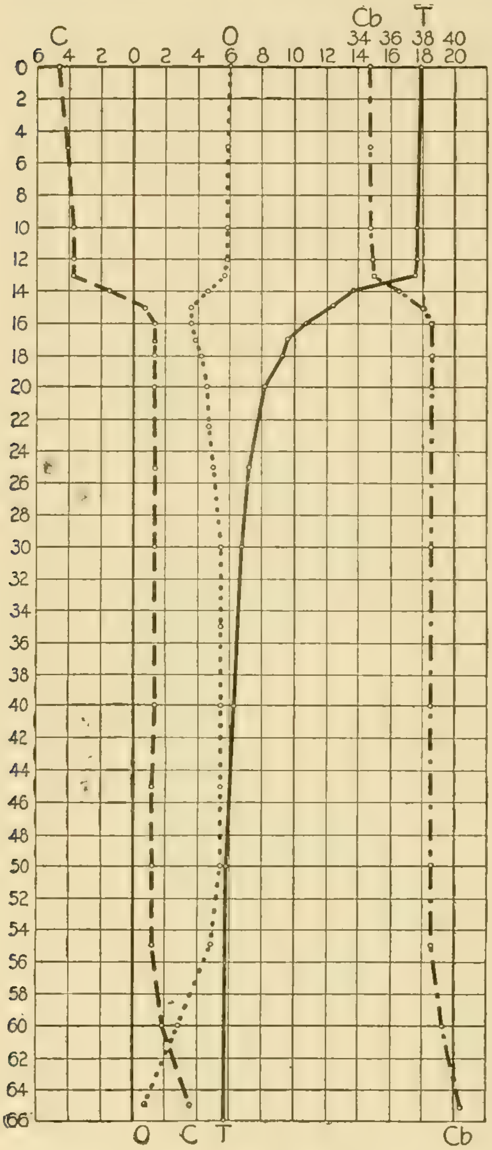


FIG. 12.—Green Lake, October 4, 1906.

dioxide, the fact being shown by a reduction of the acidity, or an increase in the alkalinity, of the water. The contrast between the carbon dioxide curves in Thousand Island and Stone lakes is sufficiently noteworthy, and this difference is apparently due to the activity of the algæ at a depth of 9 meters

and 10 meters in Stone Lake, and the consequent using up of the supply of free carbon dioxide.

MANUFACTURED OXYGEN.

In other lakes this process goes on much more vigorously than it did in Stone Lake. An illustration may be given from Beasley Lake, a little body of water in the Waupaca chain (fig. 17), where the oxygen at the thermocline rises to the maximum of about 15 cubic centimeters, and where its presence is accompanied by a marked increase of the alkalinity of the water.

It must be remembered that both the amount of oxygen and of alkalinity represent the algebraic sum of numerous complicated processes. The amount of oxygen is determined not only by the quantity manufactured, but also by that consumed, and the quantity or deficiency of carbon dioxide depends on the relation of the rate of the manufacture of starch to the rate of the decomposition of the plankton. The two processes are not necessarily parallel, and we not infrequently find, as is shown in figure 18, a great excess of oxygen, while the carbon dioxide curve shows no traces of the process which has manufactured it. In the soft-water lakes whose reaction is usually acid, the manufacture of oxygen in the cooler water may cause a change in the reaction of the water. This is illustrated by Silver Lake (fig. 19), a small pond in northeastern Wisconsin, where the oxygen maximum occurs at 7 meters, and at the same depth the reaction changes from a positive acid to an equally positive alkaline one. It returns to a slight acidity at 9 meters, and from this point the amount of free carbon dioxide rapidly increases.

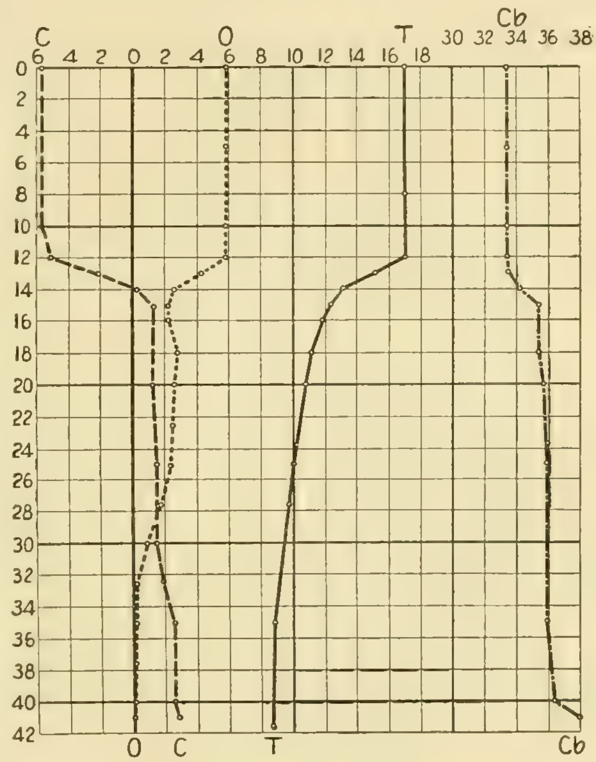


FIG. 13.—Lake Geneva, September 26, 1907.

In the smaller and shallower lakes the presence of this manufactured oxygen at the thermocline region is often of great importance in extending the inhabitable region. Beasley Lake is perhaps the best illustration of this fact. The

lake contains a great amount of fermentable material, and the oxygen disappears from the bottom water early in the spring. The lake is so small that the thermocline lies very close to the surface, remaining at 4 meters or above until late in the summer. Were it not for the manufactured oxygen, the entire body of water below the thermocline would be uninhabitable. The maintenance of the stock of this gas by the presence of the algæ doubles the thickness of the habitable stratum during the summer and the early part of the autumn. Figure 17 also shows the effect of the manufacture of oxygen on the dissolved carbonates; but that matter is too complex to be discussed here.

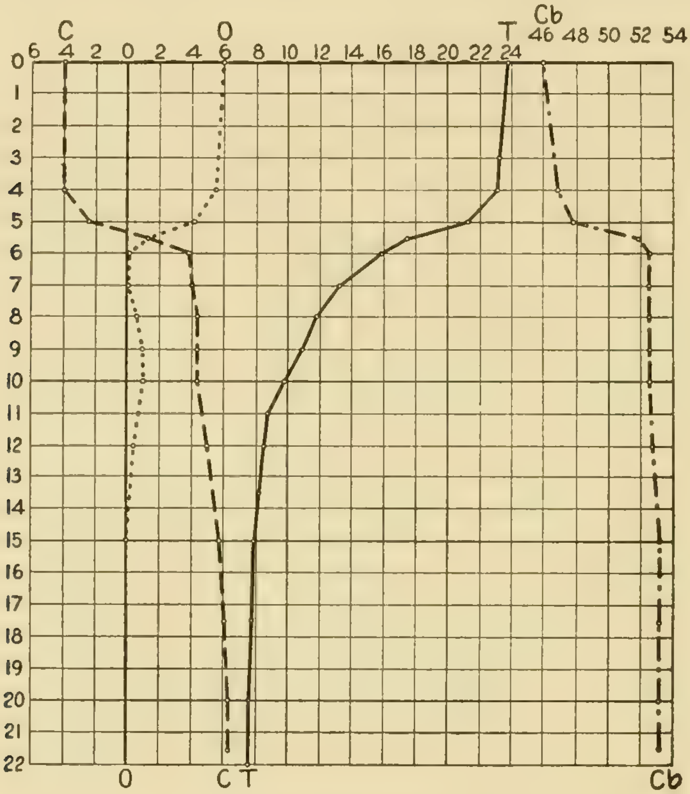


FIG. 14.—North Lake, east part, July 30, 1906.

I have spoken of Thousand Island Lake as a characteristic "lake-trout lake." So far as our observations go, the lake trout in northeastern Wisconsin is found only in lakes of this type; yet observations made in the summer of 1908 in northwestern Wisconsin show that the fish can exist in lakes of a type which would seem to be unfavorable to it. I give a diagram of the conditions in Hammill's Lake (fig. 20), a small body of water in northwestern Wisconsin, which contains a few lake trout that have been introduced. Their presence in the lake shows that they can exist in a body of water in which the oxygen extends some distance

into the cooler stratum, although the bottom water is practically or wholly devoid of the gas. Their presence in small numbers shows that such a lake is not suited to the species, and that, while it can adjust itself and survive under these unfavorable conditions, it is unable to thrive. It is not known whether it spawns under these conditions. There can be little question that the continuance of the species in this lake is due to the fact that the cool water still retains a certain amount of oxygen throughout the season.

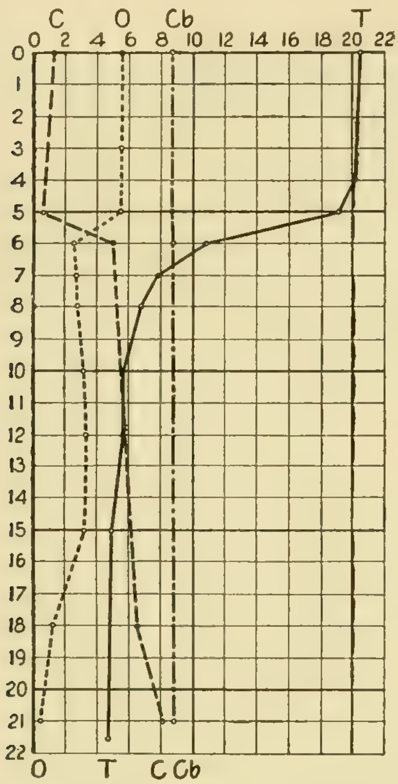


FIG. 15.—Thousand Island Lake, August 13, 1907.

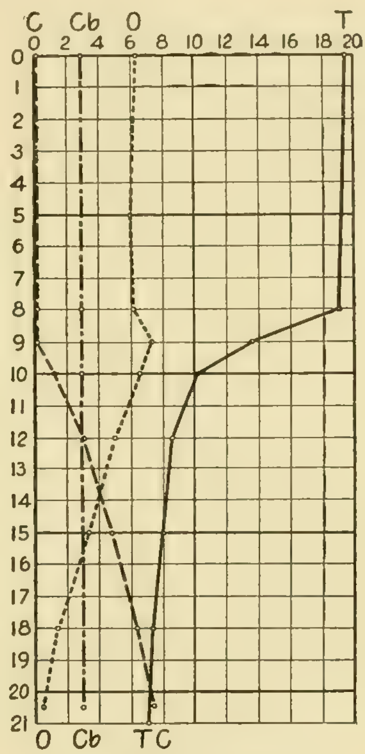


FIG. 16.—Stone Lake, August 22, 1907.

CONCLUSIONS.

I have selected for illustration these series from among the hundreds of similar observations that have been made by the Wisconsin Geological and Natural History Survey. I have not attemped to give any complete picture of the story of the gaseous changes in any lake, and many of the most important relations and results have been left unmentioned. I have brought these cases to your attention in order to illustrate two conclusions which are of importance. The first is that the cycle of the gaseous changes in a lake illustrates more readily and more conspicuously than perhaps any other facts could do what may be called the "annual life cycle" of the individual lake, showing both the

underlying resemblances of that cycle as found in different lakes and also some small part of the infinite variation in its details. These diagrams from late summer represent the culminating point of an annually recurrent series of definite changes through which the lakes pass with the season as certainly as the season returns. These changes result from the interrelation of the living beings of the lake with an environment strictly limited in its space and containing only definite amounts of food and of oxygen, to which only small additions can be made from the outside. The story of these changes is legible to him who will closely follow it. Its details differ, indeed, in each lake from those found in a neighboring lake, but on the whole it always follows along certain great lines and shows that lakes can be grouped into classes according to its major variants. Only a little of this story is now known, and many years of detailed work will be needed before even its larger facts are fully ascertained and justly interpreted. But from the few diagrams which I have given one may see that lakes present to the student a vital story, as definite, as variable, and as complex as is that of a living organism; a story to be followed by means like those needed to work out biological life histories, and one whose interest is such as to claim far more attention from science than it has received.

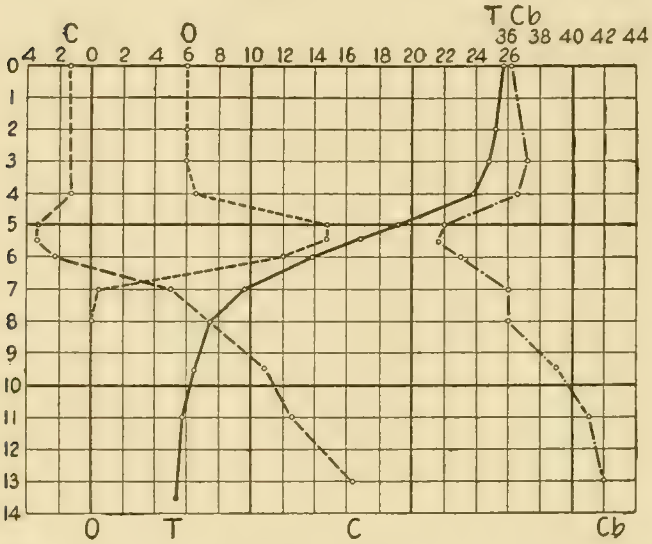


FIG. 17.—Beasley Lake, August 4, 1908.

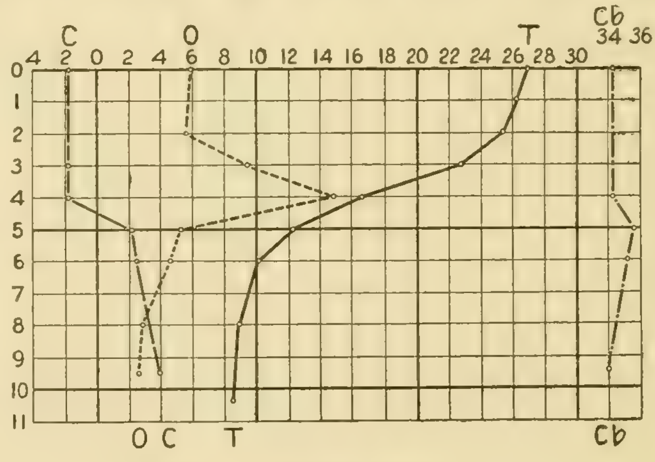


FIG. 18.—Otter Lake, August 4, 1908.

PRACTICAL IMPORTANCE OF THE SUBJECT.

If this scientific interest were all that the story affords, however, I should not have brought it to the attention of this congress, whose interest rightly lies in the fisheries. But these changes, which go on in the water of the lake, affect not only the life of lower organisms but also that of the higher ones, including the fish. No facts of environment show more clearly than do these how life determines its own conditions. On the presence of a large or a small quantity of plankton in the upper waters may depend the conditions which make the lower water habitable or uninhabitable. The relation between the volume of the lower water and the quantity of decomposing matter discharged into it

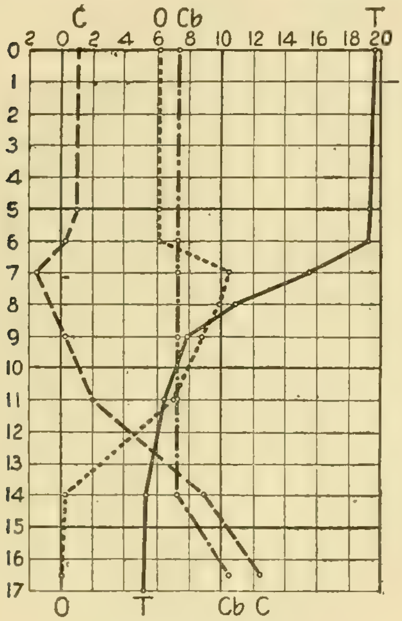


FIG. 19.—Silver Lake, August 21, 1907.

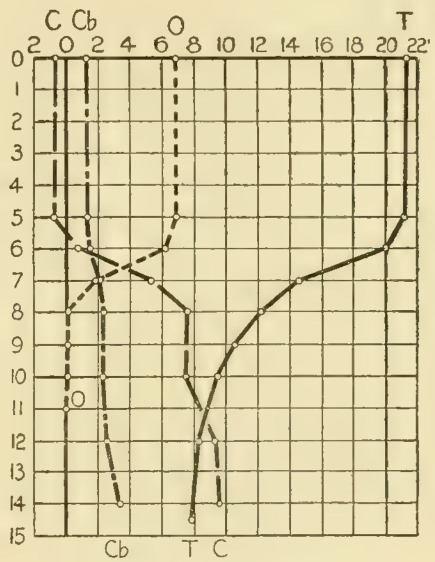


FIG. 20.—Hammills Lake, August 17, 1908.

determines whether this lower water shall be filled with animal life and support a relatively abundant population of lake trout and whitefish, or whether life of all kinds shall cease abruptly at the thermocline, or whether a scanty plankton shall indeed leave abundance of oxygen in the lower water but provide a supply of food for a scanty higher life. Thus the annual history of the lake discloses facts that are fundamentally important in determining the amount and kind of life which the lake may support and that which may wisely be introduced into it; and it becomes plain that a knowledge of them is indispensable to an intelligent use of the waters of the lake by those concerned in increasing the supply of fish.

In other words, it seems clear that a knowledge of lacustrine physics and chemistry is just as necessary to the best economic utilization of the waters of

the lakes as a knowledge of soil physics and chemistry is to the best agricultural use of the land. The problems of the lakes are complex and are not easily solved, but they are far less complex and much more easily solved than are the corresponding problems of the soil. This nation and the several states are spending hundreds of thousands of dollars annually in studying the soil. This expenditure is fully justified, not only by its scientific results but also by its practical consequences. Little or no time or money is now devoted to the similar study of the waters of the lakes. Yet no one who has followed investigations of this kind can doubt that if the lakes could be studied on the same large scale and with the same careful methods as those applied to the study of soils, results of great economic value would be obtained. It was years before the study of physics and chemistry of soils promised large economic results. Valuable practical hints have already come from the brief and imperfect study of the lakes which our survey has made, and the present situation of our knowledge indicates that a wider and more systematic study than we have been able to undertake would ultimately lead to far larger and more important conclusions. Such a study is greatly needed. The culture of fish in the innumerable inland lakes of this country should rest on the basis of scientific knowledge at least as broad and as complete as that which underlies the cultivation of our farm products. We who have in charge the maintenance of a public interest so extensive and valuable as is that of the fisheries are most of all concerned in the acquisition of that knowledge which is the only true guide of practical affairs.

DISCUSSION.

Mr. J. J. STRANAHAN (U. S. Fisheries Station, Bullochville, Ga.). I would like to ask Professor Birge a question or two. It is not closely related to this subject, although not entirely foreign. I desire to ask if you have had any experience as to the plankton and the relative amount of crustaceans and other animal life that is in soft and hard waters.

Professor BIRGE. Yes; although the matter can not be finally settled. It is a condition well known to European investigators. The hard-water lakes are much richer in plankton on the average than the soft-water, but you can not make the statement that every hard-water lake has more plankton than any soft-water.

Mr. STRANAHAN. At Guilford, in England, south of London; at Castalia, in Ohio; I think at Northville, in Michigan, and wherever I have known of exceedingly hard water, full of lime and other salts, there has been an excess of plankton. I collected plankton at Castalia to take to the World's Fair at Chicago, and with pretty carefully conducted weights the amount of crustaceans exceeded the amount of mosses and aquatic plants in which they were congregated when taken from the water. That water is so rich in lime and magnesia that it makes stone of a shingle in a year, and that is probably the greatest trout preserve in the world. At Bullochville, Ga., where I am now, our water is practically aqua pura; we can use it in photographic processes; it is exceedingly soft. We have put mollusks in it, but the different little periwinkles and other shell-covered species die in a few months, and it is not conducive to fish culture. We took two carloads of cement and buried it in our spring, and we thought we could see a marked increase in the growth of some kinds of vegetation, to say nothing of small water animals that grow in it. So I am a great stickler for the idea that we ought not to put fish hatcheries where there is not a large amount of calcareous material in the water.

Professor BIRGE. I wanted to talk about that, but with the limitations on the time I could hardly get to that part of the subject.

Doctor NORDQVIST. Those investigations Professor Birge has made are of the greatest importance in fish culture in lakes. I am of the same opinion as Professor Birge, that many of the disappointments that we have in fish culture are due to lack of knowledge about the amount of oxygen and the biological conditions of the lakes.

I would only ask Professor Birge about some slight points here in his investigations. At what time in the day was the amount of oxygen determined?

Professor BIRGE. We have made a great many attempts to discover diurnal variations in oxygen, but it is a very rare thing to find any difference in the results obtained from tests made in early morning, late afternoon, and late evening. We have continued the tests throughout the twenty-four hours. We have found very small, hardly perceptible, diurnal differences. I have received, since I came to this congress, a letter from my assistant, Mr. Juday, to whom much of this work is due, telling me that he had found such a difference in Lake Mendota.

Doctor NORDQVIST. That is just what I mean with reference to the investigations; it ought to show a difference, and I think that the curve that you have given in many of your lakes at the depths of six, seven, to ten meters may perhaps-----

Professor BIRGE [interrupting]. We have spent from two to three weeks hunting for diurnal changes right on that point. I put a party on those lakes—Otter Lakes—and we got negative results all the time; the curve remained substantially the same.

Doctor NORDQVIST. It is very interesting to hear that. Then I would be glad to learn in what way the oxygen was determined.

Professor BIRGE. In two ways: One diagram showed an oxygen line determined by boiling; and in the other it showed oxygen by Winkler's method of titration, or by one of the modifications of Winkler's method, which is a standard in the books.

Doctor NORDQVIST. Oxygen by the Winkler method?

Professor BIRGE. Yes, depending on the liberation of iodine and sodium at the end.

Doctor NORDQVIST. How was the water taken up?

Professor BIRGE. The water was taken up by a pump and hose, the latter being lowered to the proper depth, and the water brought up and kept completely out of contact with the air, so that where there was no oxygen we had like results always.

The PRESIDENT. Are there others who will contribute to the discussion of this most interesting paper?

VOLUMETRIC STUDIES OF THE FOOD AND FEEDING OF OYSTERS

By H. F. Moore

Assistant, U. S. Bureau of Fisheries

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

VOLUMETRIC STUDIES OF THE FOOD AND FEEDING OF OYSTERS.

By H. F. MOORE,
Assistant, United States Bureau of Fisheries.

Economically considered, probably the most important direct interrelation between a marine animal and plants is that existing between the oyster and its food. We have in the United States alone an industry valued at $18,000,000 per annum, which is immediately dependent upon the supply of microscopic vegetation in our bays and estuaries, a vast food resource useless to man in its original state, but of great present and still greater potential value when transsubstantiated into the flesh of oysters, clams, and other mollusks.

Various investigations have shown that about 95 per cent of the food of the oyster consists of diatoms and that most of the remainder is composed of other equally minute plants or organisms on the more or less debatable borderland between plants and animals. The oyster obtains these microscopic organisms by drawing feeble currents of water between the open shells, straining them through the exceedingly minute orifices in its gills, and passing the filtrate by ciliary action into its mouth, which lies ensconced between two pairs of fleshy palps close to the hinge of the valves. Though the currents induced are feeble they are constant, and during the course of twenty-four hours the water thus minutely strained is many times the volume of the oyster.

It is common knowledge among oystermen and oyster growers that different localities differ markedly in their powers or capabilities for growing and fattening oysters, and the results of various researches have shown that these diversities are correlated with the amount of food available to the sessile oysters. A deficiency may be due to a natural poverty of the waters, to an overpopulation of oysters, or to an absence of currents sufficient to carry the food within reach of the feeble external currents set up by the oysters themselves. Frequently all three of these factors are found to be involved where oysters grow slowly and fail to fatten.

Certain enthusiasts, some of whom should know better, have held forth the prospect of a time when the entire available bottom of our bays and sounds would be planted in oysters as densely as are the comparatively small areas now utilized. They fail to consider the fact that the natural fertility of the waters imposes some limit upon the production of oyster food, and that a vast increase in the oyster population, such as their imaginations contemplate, would undoubtedly exceed the limits which nature has set.

The microscopic vegetable life of our brackish bays and sounds is probably as abundant as it is capable of becoming under existing conditions. It is dependent primarily upon the quantity of certain mineral salts in solution, and is as strictly limited by the conditions as is the crop yield of a given area of land by the available salts in the soil. The soils can have their fertility artificially increased, but though experiments conducted by the author for the Bureau of Fisheries have shown that the same expedient is partially successful for limited areas of inclosed water, it can never be applied to open waters, as the fertilizer would be speedily carried away. In this connection, however, it is an interesting speculation whether our coastal waters are not to-day richer in fertilizing salts than they have been in the past. The denudation of our forest lands, the erosion due to faulty agriculture, the artificial fertilizers carried away from cultivated fields during periods of heavy rainfall, and the discharge of sewage rich in organic matter have undoubtedly added much to the available fertilizing content of our coastal waters, to the advantage of their microscopic vegetation.

The question of food supply, its availability, and the quantity required for a given area planted in oysters is one of vital importance to the oyster culturist. Of the total oyster supply of the United States, about five-eighths, valued at over $10,000,000, is produced on planted beds, and the future growth of the industry is dependent upon the increase of the area of private bottoms under culture. With the extension of the planting industry to new localities and the inevitable congestion in places naturally favorable for growing and fattening oysters, the value of definite data upon this subject will be greater in the future than in the past.

Empirical methods involving actual planting to determine the suitability of a locality are expensive and often wasteful, and operators with small capital are frequently deterred from taking the risk. Even though the work on a small scale may prove successful, an increase to a large commercial basis may overtax the food supply to such an extent as to make the growth of the oysters slow and their fattening impossible. A number of cases of this kind have come to the author's attention, the most noteworthy being in Lynnhaven Bay, where the increase in the area planted, though the quantity per acre is exceedingly small, has made it almost impossible to fatten oysters properly on certain bottoms formerly satisfactory.

As the economic importance of the subject merits, it has frequently been the matter of investigation and has probably attracted more attention from biologists than has any other direct correlation between marine plants and animals. The nature of the oyster's food was long ago determined and the work of the last twenty years has been hardly more than confirmatory of that which preceded it.

Dean appears to have been the first to attempt the quantitative determination of the oyster food available in the water. He employed a chemical analysis of the water to determine the albuminoid ammonia content, assuming that the results would indicate the comparative food values of different regions.

Subsequent investigators have recognized the grave defects in this method, and, including myself, have all followed the general method of Rafter. Water specimens of definite volume, usually 1 liter, have been collected either by means of a stoppered bottle or jug, from which the cork is pulled after it has been sunk to the bottom, or by a specially designed metal cylinder constructed on essentially the same principle. The suspended matter in the specimen, a large part of which often consists of sand, mud, and débris, is then concentrated in, say, 10 cubic centimeters of water by filtration through sand or precipitation in an Erlenmeyer flask after the addition of a few drops of formalin. A definite quantity of the filtrate is then removed after agitation and the food organisms counted in a Rafter cell, the calculated number of such organisms per liter being regarded as an expression of the food value of the water.

This method has two defects, the first of which is that the water specimen is not drawn from the stratum tenanted by the oyster, but solely from a height of about 12 inches above the bottom. It would be possible to correct this defect by using a shorter, broader bottle or specimen cup, but as the water flows rather slowly into the necessarily narrow inlet, there would enter with it a considerable quantity of material stirred up when the instrument strikes the bottom. As the amount of this material would vary with the bottom, the impact, and the currents, a more serious source of error would arise and the results would become worthless.

To obviate these difficulties I have designed the type of bottle illustrated in text figures 1 to 5. It consists essentially of a brass barrel of a capacity somewhat over 1 liter, two conical valves, and a tripping device. The lower valve is fixed at a height of 2 inches above a broad base, which prevents the instrument from sinking in soft mud, but the barrel and upper valve slide freely on a central column or rod. The instrument is set by engaging the lug (F) over the inclined surface (G) of the stirrup or tripping device (CDEG), which suspends the upper valve (B) and the barrel (A) so as to leave a gap of 2 inches between the two valves and their respective seats, the stirrup being maintained in position by tension on the cord by which the instrument is lowered. By rotating the cam (H) so as to pinch the cord between it and the collar on top of the upper

valve, the instrument may be locked in the set position, but it is automatically unlocked when it is raised by the cord.

As the instrument is lowered there is a free flow of water through the barrel, so that at any given time its contents are taken from the stratum in which it

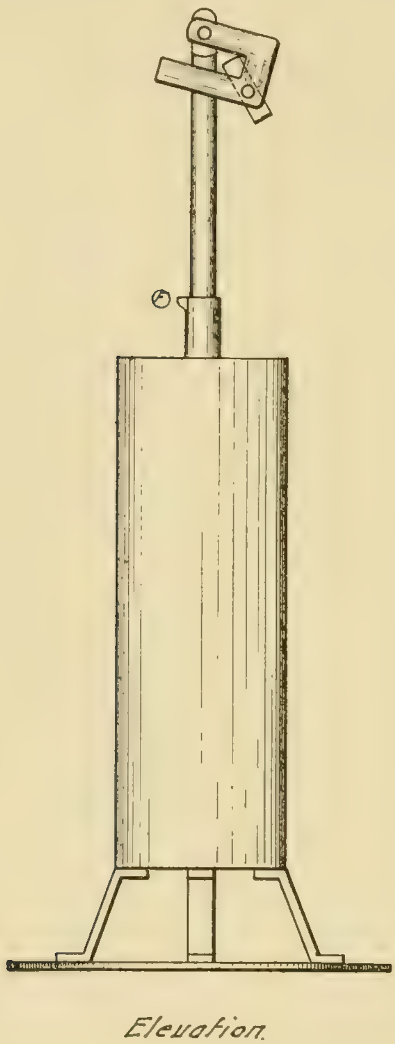


FIG. 1.

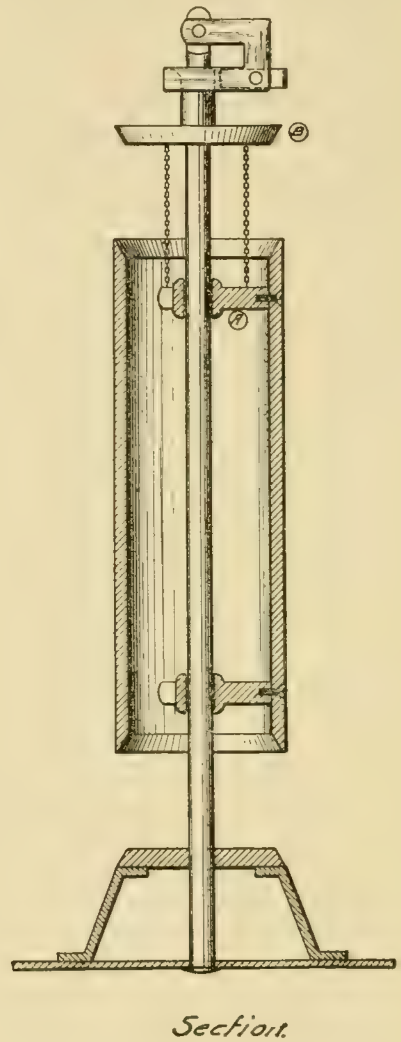


FIG. 2.

Water specimen cup.

rests. When bottom is touched the tension on the cord is relaxed, the tripping device instantly releases the upper valve and the barrel suspended from it, and they fall into their respective seats, inclosing a sample of water before it can be contaminated by the stirred-up bottom deposits. As the barrel is 10 inches

long, the water inclosed is a vertical column of the stratum lying between 2 inches and 12 inches above the bottom, and as the currents do not flow over the beds in horizontal strata, but roll over and over, this specimen is regarded as a fair sample of that in which the oysters are bathed.

The instrument is now used in Massachusetts, Maryland, Virginia, and Louisiana, and actual tests have shown that it takes a water specimen much cleaner and freer from mud and extraneous materials than do the instruments previously employed.

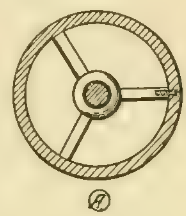


Fig. 3.—Cross section at A, figure 2.

The other defect of the old method of determining the food value of oyster-producing waters arises from the practice of using the number of diatoms or organisms per liter as the measure of their productiveness. It is well known that diatoms, which usually constitute upward of 95 per cent of the food of oysters, differ greatly in size and the species vary in comparative abundance in different regions and from season to season in the same locality. When a numerical expression is employed, it follows therefore that a multitude of small organisms may give an apparent superiority to a water specimen as compared with another containing a smaller number of a species of vastly larger size and much greater aggregate volume, and my own experience has shown cases where this error amounted to nearly 400 per cent. The method is attended with grave error as applied to even limited regions and is wholly untrustworthy as a basis of comparison between widely separated localities. It gives seemingly quantitative results, but these, not being volumetric, are deceptive.

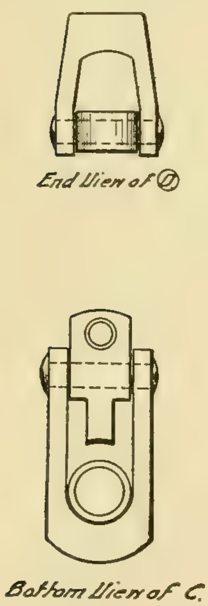


Fig. 4.

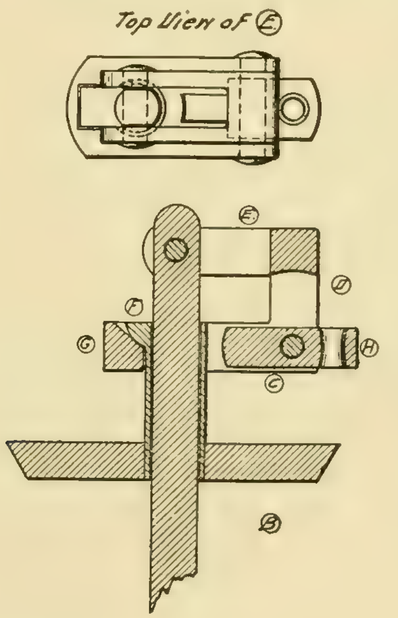


Fig. 5.

Details of tripping device of water specimen cup in figures 1 and 2.

Direct volumetric determination can not be made on account of the presence of considerable volumes of sand, mud, and extraneous débris in the filtrate, these materials greatly exceeding the food organisms in volume. Grave attempted to overcome the difficulty by listing the food organisms by species,

but this arrangement, though an advance on previous work, is not capable of comparative use, and any error in identification, not unlikely to occur with persons not diatomists, would be misleading to future investigators.

To overcome these difficulties I have for several years used the following indirect method, which has given satisfactory results. The diatoms and other food organisms are collected and counted, as before indicated, and are listed by species, although their identification by their correct names is not essential. Careful outline camera lucida drawings are made of the zonal and valvular aspects of a number of specimens of each species, and their cubic contents are calculated by geometric methods from planimeter measurements of the drawings. The average of a number of such calculations will give the average relation of the volume to the product of length, breadth, and thickness of the species. Using this relation and the average of a number of micrometer measurements of the specimens themselves, a simple calculation will furnish an approximately correct expression of the average volume of the species in the region under investigation. If these volumes be employed as multipliers into the numbers of the respective species, determined from the counts in the Rafter cell, we have an approximately correct volumetric expression for the amount of the food content of each specimen of water. As the most convenient unit of measurement I have adopted Van Heurck's "c. d. m." (0.01 millimeter), the unit of volume being the cube of this, "cu. c. d. m." (0.000,001 cubic millimeter). The following is an illustration of the data required for each species:

Synedra commutata (Matagorda Bay); average length, 4.7 c. d. m.; breadth, 0.5 c. d. m.; thickness, 0.5 c. d. m.; volume $= 0.6\ (l \times b \times t) = 0.7$ cu. c. d. m.

This method sounds elaborate in its narration, but has not shown itself to be cumbersome in practice, and, moreover, it appears to be the only method so far proposed which gives data of real value. The results are directly comparable with those obtained in other waters or with those reached in the same waters at different seasons. Five hundred or 600 determinations have been made in the past two years, and, for reasons shown below, the procedure generally was found to require but little more labor than the older misleading and less accurate method.

In oyster investigations it is customary to take a large number of water specimens at adjacent stations, and as the nature of the food content of each varies in quantity rather than in the character of the organisms, the measurements of eight or ten species will apply to all water samples from the locality. Only those organisms need be measured which examinations of the stomach contents of the oysters show to be important as food. The counts have to be

made, whatever method be employed. In Matagorda Bay, where the present method was first used, about 150 specimens of water were examined and the additional time required was not over 10 per cent. The following table shows the results and the manner of tabulation, as well as the differences in results attained by the numerical and the volumetric methods:

FOOD VALUE OF WATERS OF MATAGORDA BAY.[a]

[Roman figures indicate volume of organisms, or food value. **Bold-face figures** indicate number of organisms.]

No.	Species.	A. Between Sand and High Mound signals.	B. Between High Mound and Lake signals.	C. Between Mad Island, West, and Lake signals.	D. Between Shell Island and Mad Island reefs.	E. Between Dog Island and Shell Island reefs.	F. Between Dog Island and Pavilion signal.
1	Coscinodiscus crassus	**500**	----------	**917**	**250**	**100**	**500**
2	lineatus	121,805 **3,483**	141,470 **4,042**	142,905 **4,083**	183,750 **5,250**	141,750 **4,050**	122,500 **3,500**
3	excentricus	10,500 **1,750**	17,502 **2,917**	17,760 **2,960**	12,000 **2,000**	5,550 **925**	12,000 **2,000**
4	Navicula didyma	4,125 **375**	6,413 **583**	9,625 **875**	11,000 **1,000**	---------- ----------	---------- ----------
5	elliptica	1,250 **125**	1,660 **166**	4,160 **416**	2,500 **250**	1,000 **100**	5,000 **500**
6	arenaria	937 **375**	1,145 **458**	1,688 **675**	3,750 **1,500**	250 **100**	1,250 **500**
7	Amphora ovalis	2,500 **500**	---------- ----------	625 **125**	---------- ----------	500 **100**	---------- ----------
8	Pleurosigma fasciola	**250**	----------	**125**	----------	**425**	----------
9	obscurum	----------	----------	**125**	----------	----------	----------
10	intermedium	**125**	----------	----------	----------	**225**	**500**
11	tenuissimum	**375**	**292**	**125**	**1,250**	**350**	**500**
12	angulata major	----------	----------	----------	----------	----------	**250**
13	Synedra commutata	5,600 **8,000**	6,650 **9,500**	9,100 **13,000**	25,550 **36,500**	8,155 **11,650**	1,400 **2,000**
14	sp	1,750 **500**	1,225 **333**	3,790 **1,083**	1,750 **500**	2,275 **650**	875 **250**
15	Melosira distans	52,500 **2,625**	68,340 **3,417**	73,340 **3,667**	35,000 **1,750**	18,160 **908**	20,000 **1,000**
16	sp	**250**	----------	**675**	----------	----------	----------
17	Pyxilla sp	----------	----------	----------	----------	**200**	**250**
18	Other diatoms	**1,250**	**500**	**292**	**250**	**300**	**1,000**
19	Prorocentrum micans	18,375 **2,625**	29,456 **4,208**	8,750 **1,250**	8,750 **1,250**	---------- ----------	3,500 **500**
	Total volume, or food value	219,342	273,861	271,743	284,050	177,640	1[illegible]6,525
	Total number of organisms	**23,108**	**26,416**	**30,393**	**51,750**	**20,083**	**13,250**
	Prairie shore	208,527	287,737	239,024	259,875	159,937	89,925
	Middle of bay	259,774	345,200	267,000	274,350	177,900	254,925
	Peninsula shore	190,049	188,450	314,412	317,625	193,770	153,725

[a] From Survey of Oyster Bottoms in Matagorda Bay, Texas, by H. F. Moore. Bureau of Fisheries Document 610.

FOOD VALUE OF WATERS OF MATAGORDA BAY—Continued.

No.	Species.	G. Between Pavilion and Three-mile signals.	H. Between Three-mile and Seven-mile signals.	I. Between Seven-mile and Grass signals.	J. Between Grass and Dressing Point signals.	K. Live Oak Bay.	L. Above Dressing Point.
1	Coscinodiscus crassus	375	292	792	200	-	-
2	lineatus	135,625 3,875	163,310 4,666	198,310 5,666	118,720 3,392	157,500 4,500	140,000 4,000
3	excentricus	17,250 2,875	13,248 2,208	16,002 2,667	9,150 1,525	-	3,498 583
4	Navicula didyma	-	2,750 250	3,212 292	2,013 183	-	4,587 417
5	elliptica	2,500 250	4,170 417	12,500 1,250	-	-	2,500 250
6	arenaria	3,438 1,375	730 292	1,458 583	2,500 1,000	3,750 1,500	5,420 2,167
7	Amphora ovalis	625 125	1,250 250	-	830 166	3,750 750	1,665 333
8	Pleurosigma fasciola	-	166	166	-	-	166
9	obscurum	-	-	125	-	750	250
10	intermedium	-	-	166	492	-	583
11	tenuissimum	1,500	750	166	883	750	883
12	angulata major	125	166	167	-	-	-
13	Synedra commutata	962 1,375	1,517 2,167	642 917	1,686 2,408	1,575 2,250	1,166 1,666
14	sp	5,250 1,500	1,793 541	581 166	4,812 1,375	5,250 1,500	11,081 3,166
15	Melosira distans	10,000 500	-	20,000 1,000	13,500 675	-	-
16	sp	250	542	167	208	-	333
17	Pyxilla sp	250	167	125	100	750	-
18	Other diatoms	-	125	-	517	2,250	500
19	Prorocentrum micans	2,625 375	5,832 833	7,875 1,125	14,581 2,083	5,250 750	11,669 1,667
	Total volume, or food value	178,275	194,600	260,580	167,792	177,075	181,586
	Total number of organisms	14,750	13,832	15,540	15,207	15,750	16,964
	Prairie shore	151,050	162,900	191,700	182,470	-	-
	Middle of bay	186,599	182,925	357,650	152,525	-	-
	Peninsula shore	189,675	238,349	232,250	168,674	-	-

In the study of the food actually consumed by the oyster, it has been regarded, heretofore, as sufficient to remove the stomach contents by means of a pipette inserted in the mouth or through an incision in the body walls. This method extracts but an indeterminate portion of the undigested food in the stomach, a considerable proportion remaining in the folds of that organ and in the wide openings of the hepatic ducts, and it removes practically nothing of the intestinal contents. For quantitative work the method is very defective, and it is useless as a basis for those studies of food consumption and the rate of feeding which must have an important place in the oyster investigations of the future.

In order to remove the entire contents of the alimentary canal, I am now using the apparatus illustrated in figure 6, which is essentially a combination of stomach pump and enema, effectually irrigating the entire digestive tube. It consists of a reservoir (A), connected by a flexible siphon tube with a glass canula (B) ligated in the rectum, and of an aspirator (C) connected through the medium of a vial or test tube (D) with another canula (E) inserted in the mouth.

The canulas are made of glass tubing, and their tips are held for a moment in a Bunsen flame to produce a burr, which prevents their slipping from the ligature.

The operation of the apparatus is as follows: The reservoir (A) is lowered until the water surface is about level with the stage F. The oyster is carefully

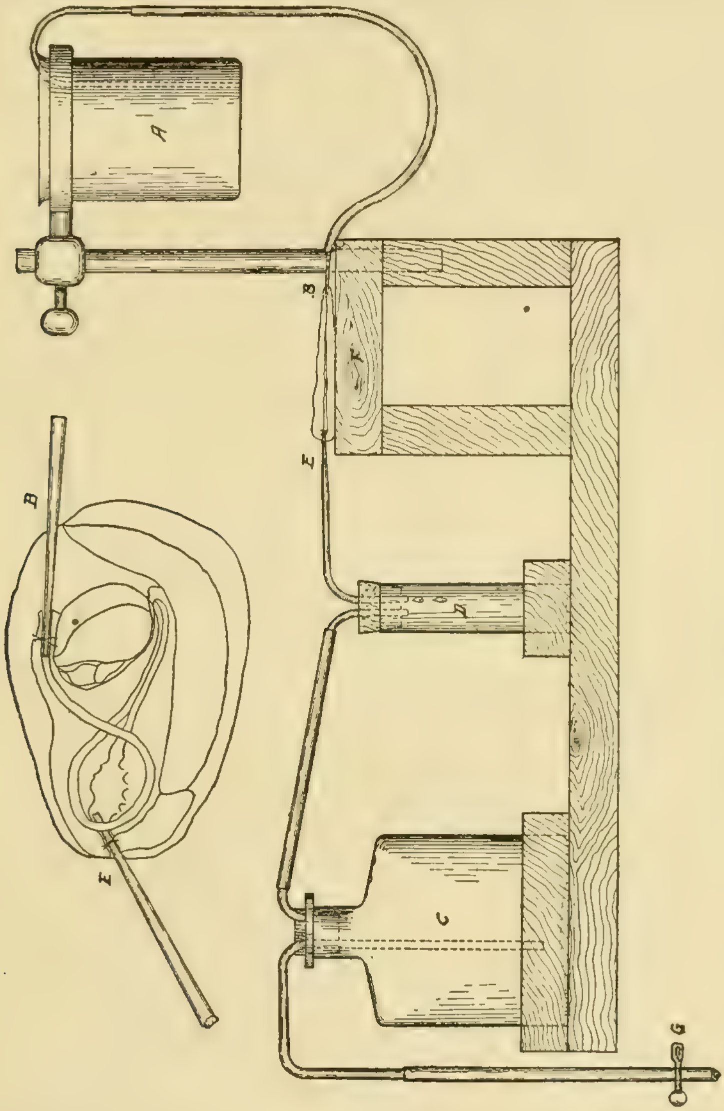


FIG. 6.—Apparatus for extracting contents of alimentary tract of oysters.

removed from its shell and placed on the stage, its rectum is slit for a distance of about one-eighth inch from the anus to facilitate the insertion of the canula, which is ligated in position by means of a needle and thread. The oral canula, which has a wider opening, is inserted in the mouth and ligated by means of a

needle and thread carried through the tissues. The pinch cock (G) is then released on the siphon of the aspirator, which exhausts the air from the vial or tube (D), draws out some of the stomach contents, and causes a slight collapse of the walls of the alimentary canal. The reservoir (A) is then raised until a flow of water is established through the rectum with a resultant slight turgescence of the intestine. There is thus established a current of water running into the rectum, through the intestine, and out of the mouth, carrying with it eventually the entire alimentary contents, which collect in the tube (D). To facilitate the dislodgment of the more or less impacted fæces, the intestine is occasionally gently tapped with the handle of a scalpel or dissecting needle. With one apparatus about six oysters per hour can be opened and operated on, and dissection shows the entire alimentary canal to be freed of contents. The contents of the tube are treated with a few drops of preservative and are concentrated, by precipitation and the removal of the supernatent water, to a standard volume of 5 or 10 cubic centimeters, after which the organisms are counted by the Rafter method and the volume calculated as previously described. It is usual to take the average of five specimens as the measure of the food content of a given lot of oysters.

For studying the rates of feeding of oysters under different environmental conditions, I have recently used the following experimental methods, which have been found effective:

Pieces of sheet rubber (dentists' "rubber dam") about 8 inches square, called "aprons," are prepared by cutting out of the middle semicircular "windows" of about 2 inches radius, over which pieces of no. 25 bolting cloth are cemented with a thick ethereal solution of rubber. A slit about 5 inches long is cut in the rubber parallel to and about ½ inch below the long diameter of the window.

A number of oysters, about 5 inches long, are then thoroughly scrubbed with a brush, washed in fresh water, the shells covered with a thin layer of Portland cement so as to fill all cavities and smooth irregularities in their surfaces, and thoroughly dried in the air.

Each is then inserted in the slit in the middle of an "apron" in such position that the edges of the slit approximate the line running from the dorsal side of the hinge to the point of insertion of the gill at the edge of the mantle. The edges of the slit are then pasted to the shell with rubber solution, care being taken to provide a small fold in the apron at the lip of the shell, to carry it around the dorsal side of the hinge so as not to interfere with the opening of the valves, and to see that there are no gaps between the shell and the rubber at any point.

Security of adhesion can be promoted by first giving the proper parts of the shell several coats of thin rubber solution, the final cementing being performed with a thick paste made by squeezing the ether-softened crude rubber through cheese cloth and reducing it to the desired consistency by shaking it in ether.

The oysters prepared in accordance with the foregoing description are then placed for about three days in filtered sea water, renewed morning and night, at the end of which time they are practically purged of food and usually gaping with hunger. The intestinal contents of five are then determined by means of the apparatus and methods already described.

The remaining oysters are now placed each in a 6-inch Petri dish, the shells resting on a wire support to raise them above the bottom and lying so that the deep valve is downward and in such position that the cloacal or excurrent chamber of the oyster lies below the apron and the oral or incurrent chamber above it. The "apron" is then confined to the sides of the dish by means of a rubber band or cord, and a layer of sand is placed over the window and the surrounding rubber to serve as a filter, as shown in figure 4. A piece of cheese cloth tied over the sand will prevent its being washed away by currents or disturbed by inquisitive fishes and crabs.

When the oysters thus prepared are transferred to their natural environment they are as free to open their valves and feed as if they had never been removed from their beds; the oral chamber is in unobstructed communication with outside waters while the excurrent chamber discharges into the Petri dish, where the fæces are retained while the expelled water passes through the filter. Oysters prepared as described have been kept under close observation under otherwise natural conditions and appeared to feed as freely and normally as neighboring specimens that had never been disturbed. The fæces drop into the dish in a little heap of demicylinders, while extraneous matter was excluded by the apron and filter.

At the end of three and six days, respectively, lots of five of these oysters are taken up, their intestinal contents removed by the method already described and added to the fæces collected from the dishes. As about 95 per cent of the food consists of diatoms whose tests pass unchanged through the alimentary canal, it is evident that by calculating the volume of the combined food organisms of the fæces and alimentary canals by the methods described and deducting the volume of the residual intestinal contents, as determined from the lot of five starved check oysters, we can arrive at a volumetric expression of the average rate of feeding. Determinations of the diatomaceous content of the surrounding water made at intervals during the experiment supply the data for the necessary correction to be applied for dead diatom frustules ingested by the oysters under experiment.

It is perhaps not necessary to use starved oysters for these experiments, but they have been used in order to insure the prompt commencement of feeding as soon as returned to the water, unstarved specimens sometimes "sulking" after repeated handling. A check upon possible error due to any abnormal

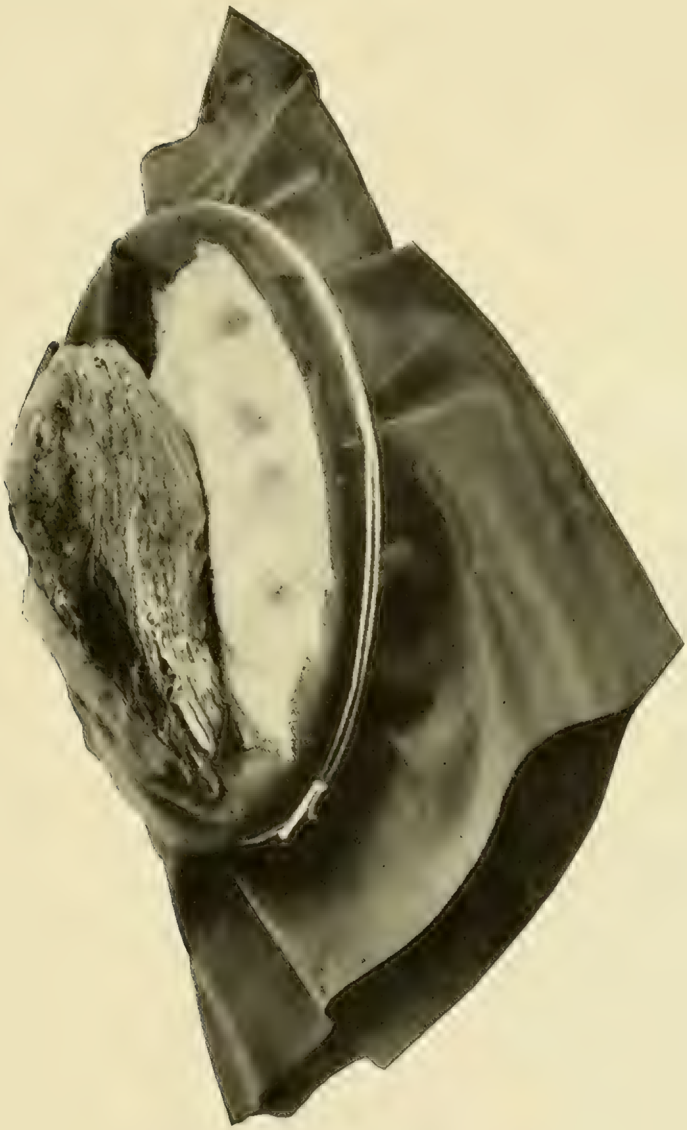
appetite at the beginning of the experiment is provided by comparison of the results obtained in the two lots fed for different periods.

My first experiments were with bolting cloth aprons, but it was found difficult to keep them covered with sand, especially close to the edges of the dish, and also to secure good adhesion between the shell and the apron. These defects in some cases permitted the infiltration of fine mud and other extraneous matter. Such difficulties have been obviated by the use of sheet-rubber "aprons" as described. The latter have been in use for four or five months and have proved satisfactory, but there has not been time for the tabulation of the quantitative results.

It is believed that the apparatus and methods of research above described furnish for the first time efficient instruments for strictly quantitative studies of the food and feeding of oysters and similar mollusca, and they also furnish data for determining the amount of water filtered through the gills. In addition to the scientific interest attaching to the studies it is believed that they will lay the foundation for valuable economic data. As is well known to those who have made a study of the oyster fisheries, much time and money is lost in futile attempts to grow oysters in localities which eventually prove unsuitable. In many cases these failures are due to a paucity of food, the oysters failing to fatten. If there could be determined the minimum food unit requisite under varying conditions of bottom, currents, and density of oyster population, the waste of time, money, and effort in useless planting could be largely prevented.

As a preliminary to the determination of such unit, it is necessary to determine with accuracy the relations existing between the oysters and the plants which constitute their diet. We must know the exact relation existing between the food consumed by oysters which are rapidly growing and fattening and by those which are not. We must determine how much more food an oyster will consume in strong currents than when living in sluggish waters equally rich per unit of volume, and it will be necessary to learn also the water food content required to supply the minimum requisite under varying conditions of current.

The experiments already conducted have shown that all of these data can be obtained with considerable accuracy by the means above described, and by conducting further research in regions such as Lynnhaven Bay, where the quantity of oysters on the bottom over considerable areas can be approximately arrived at, they can be given concrete application. The formulation of the desired unit will require much patient research and observation, the study of currents, of the behavior of oysters under various natural conditions, and possibly of the reproductive activity of diatoms and other food organisms, but it is believed that we are now in possession of instruments which warrant an attempt at the solution of the problem.



Oyster with filter apron for study of feeding.

A PLAN FOR AN EDUCATIONAL EXHIBIT OF FISHES

By Charles F. Holder

Paper presented before the Fourth International Fishery Congress
held at Washington, U. S. A., September 22 to 26, 1908

A PLAN FOR AN EDUCATIONAL EXHIBIT OF FISHES.

By CHARLES F. HOLDER.

In preparing an educational collection of fishes I should divide the subject into the two classes of game fishes and economic or edible fishes.

The game fishes would include in a general way tarpon, bonito, white sea bass, black sea bass, gray and other snappers, grunts, barracuda, ladyfish, bluefish, weakfish, swordfish (*Tetrapturus*), black grouper, yellowtail, long-finned tuna, yellow-finned tuna, whitefish (California), sheepshead (Florida), swordfish, amberfish, channel bass, striped bass, salmon (various kinds), trout (all kinds), black bass, and all the game fishes that can be taken with a rod and afford good sport, eliminating all doubtful ones, such as rock bass, sunfish, etc.

I would have papier-maché casts made, showing a side of the fish colored to life, to hang on a wall; or, better, half of a fish, the skin drawn over a model of wood or plaster. A label under it would give its common and technical name, geographical range, and a number for reference to a catalogue, which would be called "Guide to the Exhibit of Fishes." Near the fish I would have a framed photograph of a living specimen, taken in a tank where the natural surroundings have been provided. At Avalon, Cal., I have such a tank about 3 feet long and 8 inches wide. I can arrange this tank with natural grouping of weed in which the fish lives, place the specimen in it, and with camera near the glass obtain a perfect picture. I have photographed all the southern California small fishes in this way. I would exhibit also a drawing of the eggs, or photograph of the nest, if the fish makes one. The catalogue number, we will say, is no. 1, "Tarpon, not edible, very valuable as game fish; scales valuable in commerce. Range, the world, in latitude ——; — species. Tackle, 9-ounce rod over 6 feet, nine-thread —— line; bait, mullet. Famous tarpon fishing grounds, Aransas Pass, Tex.; Tampico, Mexico; Florida (south coast); India. Authorities (——)." Here quote the best angling authorities and the books in which technical descriptions can be found. Also give the name of authoritative tackle dealers who are specialists; size of adult fish; food, seasons, fresh or salt water, etc. This book could be sold for cost, say 10 cents, or the data could be printed cheaply and given away. By this means a visitor walking down the room would contemplate a life-size facsimile of the fish, beside its

skeleton would read its name and geographical range, see a picture of it alive, a photograph or cut of its nest, and in the guide read in a few words its complete story and economic value; and he could, if desirous of studying it, make a note of the various works referred to. If the fish has a decided economic value, as the salmon, I would have near an album of photographs showing the complete history of the fishing on the Columbia, photographs of nets in use, canning, etc.; and if very important, show models of the nets used.

In some part of the room in the game fish section I would have a case of tackle for game fishes, tackle which could be provided by a good firm. Here would be shown the tackle for tarpon, tuna, swordfish, black sea bass, etc., according to the accepted classification. There would be a perfect 9-ounce rod, with samples of nine-thread lines from all the big makers. Then the reels used for this rod, the gaffs that go with it, photographs of the boats of the angler who follows these fishes, photographs of the fishing localities in California, Florida, and elsewhere. This would refer to a number in the book in which would be given an account of the economic value of the sport, an estimate of the amount invested in rods, reels, and lines. It could be shown, as an example, that California considers that anglers alone spend over $1,000,000 annually in that State. Each rod, reel, and line would have prices marked on them showing cost. There would be the reference to books on rod making, line manufacturing, etc., to be found in public libraries. Then would come the 6-ounce sea rod, the casting (bait) rods, and the various other rods; then salmon rods (salt-water salmon, fresh-water salmon), showing every possible rod and line. Then flies numbered on cards—English, American, Irish; spoons, imitation live baits, nets, gaffs, fish baskets; and with each rod a photograph of an angler holding that rod, showing it in action. In a word, the whole story would be told, and in the guide would be read the number of thousands of dollars invested in salmon as sport, for the renting of rivers, maintenance of hatcheries, cost of tackle. Then the trout rods of all kinds, flies, leaders, pictures showing silk, worm, or gut maker, bamboo from which the rod is made, fly hooks, creels, nets, etc., bait cans, gut leader cans, worm cans, bait minnow cans, etc.; pictures of trout, anglers casting, records of long-distance casting for accuracy, etc. Coming to black bass, there would be the same plan—rods, pictures of the black bass, skiffs of the St. Lawrence River, etc. In fact, collect about this tackle section every possible factor that will tell the story of the utilization of the fish, its value to man, the number of guides and boats employed, cost of boats, reference to manufacturers.

In this way, passing tarpon, trout, tuna, salmon, and other rods the visitor would come to boats. Here I would show a typical St. Lawrence skiff with dummy figures, the angler in the stern holding the rod, the boatman behind him. I would show also a typical Catalina launch for big game fishes, fully

equipped with figures. Then other boats could be shown in photographs. All the dealers in fishing boats would contribute cuts or photographs of their models and equipment, such as steel fishing boats, the engines used in modern fishing boats, etc.

In the section relating to bait for game fishes I would show "cast" and other nets, flying-fish gill nets, etc., used by boatmen to catch bait, the colored cotton lures used by Japanese in America for sardines, etc. In a corner I would have a complete photographic set of California game fishes, showing the angler standing with the fish, and the exact tackle used.

Next I would show photographs or models of famous angling clubhouses, as Tuna Club, Aransas Pass Tarpon Club, Asbury Park Club, New York Club, Salmon Club, California Light Tackle Club; and in the guides would be found the estimated value of club houses. For example, Avalon, Cal., has the $7,000 house of the Tuna Club; the two angling clubs there have 2,000 members and $1,500 in cups; the boatmen have $150,000 invested in angling boats, glass-bottom boats, and others, all relating to sport. Over 175,000 persons go to this place every year for the fishing alone. Transportation to the island and back costs $2.50, living expenses $2 to $10 a day, and from $5 to $10 per day is expended for hire of guides and launch; all of which amounts to a large sum, representing the economic value of the sport at this one island. A collection of photographs of the famous angling piers of the Pacific coast could be shown. Some of these cost $100,000 and are given over entirely to the angler.

In one section of the sport appliances I would show all kinds of spears, as grain, harpoons, turtle pegs, floats, lances, etc., shark harpoons, etc., and every appliance used in taking a game fish in sport. This collection could be augmented by photographs of anglers taken at the great angling tournaments of the country, as that of the California Tuna Club, from May to October, and the various casting tournaments of the trout, bass, and salmon clubs. There should be in this hall copies (photographs) of the most famous paintings of trout, salmon, etc., by the best artists, and series of photographs could be given showing the peculiar economic uses to which game and other fishes are put, such as the light of the candlefish, tarpon scales as post cards, fish scales in art, shark skin as leather, ear stones of white sea bass (California) as jewelry, etc., eyes of Santa Catalina fish as pearls, hardened by a peculiar process. In connection with the exhibit of game fish tackle I would have a case or collection called "ancient angling appliances." Here I would show the fishing tackle of the ancient Americans, as, for California, the abalone hooks, and others in all stages of making from the circular disk to the punctured disk, and then the complete hook as found in the mounds; hooks with the barb on the outside; the kelp line; spears used for fishing, bone, stone, wood; fish clubs of whalebone; in fact, make

this tell the complete story of ancient fishing methods in America. I would follow this with the fishing appliances of the last two centuries, so that it would be possible for a student or angler to observe at a glance the complete evolution of the rod, line, or hook, sinker, or the art of angling as a sport in America. He could turn from the shell hook to the perfect series of modern hooks of all kinds and varieties.

In connection with this educational display of fishes, if in a large museum, I would advocate the placing of a library of sport where the principal books on angling from the time of Walton down to to-day could be seen or consulted daily. Thus a visitor could turn from the ocular demonstration to the literature of the subject. I would also include a map or maps colored to show the localities and distribution of all game or food fishes. Thus could be seen at once the localities for tarpon, salmon, black bass, etc., as on the sportsman's or angler's map published by various railroad interests.

If the museum had special days or had lectures to teachers or others, a series of lectures could be illustrated by the stereopticon, showing the great trout streams of the country and the famous fishing grounds of California.

In the field of economic fishes, interesting histories could be given and illustrated by photographs, valuable fisheries to be given as types being the sardine fisheries and canneries of San Pedro, Cal.; the sardine fisheries of France and Italy; the tuna fisheries of Sicily; tuna fishing at Santa Catalina; jack fishing in Florida; the shad fisheries of St. Johns River, St. Marys River, etc.; the various fishes of New York; bluefish fishing in New England; the whitefish fisheries of the Great Lakes; grouper fishing in California; sand-dab fishing at Santa Catalina; the red-snapper fisheries of the Gulf of Mexico; the mackerel fisheries of Gloucester; the cod fisheries of the Grand Banks; the mullet fisheries of Florida; swordfishing off Cape Cod, Block Island, etc.; all of which have their literature, and photographs of which can be had to form a most interesting collection.

Under each fish model, or facsimile, I would place a perfect skeleton of the fish as before, with specimens of its scales mounted, and in the guide would be given brief references telling the story of the economic value of the fish, its use as food for other fishes, or as guano, as in the case of dogfishes on the Maine coast.

In this connection some data should be collected to show the work of private organizations, the national and the state governments in stocking streams and otherwise aiding the interests of the angler and commercial fisherman, so that there would be represented the evolution of angling and the complete history of the fishes, either in sport or in economics, not as a dry and prosaic exhibit, but as a great popular picture of a valuable public interest.

A PLAN FOR AN EDUCATIONAL EXHIBIT OF FISHES

By Roy W. Miner

Assistant Curator, American Museum of Natural History

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908 and awarded one-half the prize of one hundred dollars in gold offered by the Museum of the Brooklyn Institute of Arts and Sciences for the best plan for an educational exhibit of fishes

A PLAN FOR AN EDUCATIONAL EXHIBIT OF FISHES.

By ROY W. MINER,
Assistant Curator, American Museum of Natural History.

An exhibit to be educational must be attractive as well as instructive; that is, its features must be so arranged as to stimulate attention, and when that is accomplished, to offer instruction that will be appreciated not only by the casually interested observer, but also by those who have come for the express purpose of learning, namely, the pupils and teachers of the public schools, university students, and others specially interested. Its lessons therefore must be simple, direct, and systematically arranged.

But when we endeavor to accomplish this end with an exhibition of fishes, certain special problems are involved. In the first place, the material is refractory and difficult to prepare effectively for exhibition; in the second place, the very monotony of the fish form makes the study of arrangement a matter of special concern. The consideration of these questions will be taken up as follows: (1) The nature of the material available for exhibition will be discussed; (2) various methods for arranging and labeling the exhibit will be brought forward; (3) supplementary suggestions will be offered for rendering the exhibit instructive and attractive, and (4) the paper will close with a provisional list of fishes to be exhibited.

The writer does not pretend that he has solved the question of fish exhibition, but offers these suggestions partly as the result of his attempts in this direction and partly as tentative schemes which may aid in meeting some of the difficulties.

NATURE OF THE MATERIAL TO BE EXHIBITED.

The material for exhibit may be (1) alcoholic specimens, (2) mounted and painted skins, (3) casts, (4) models, (5) skeletons, (6) colored plates and photographs, (7) groups.

(1) *Alcoholic specimens* should be used but sparingly, as for the most part they have little exhibition value because of distortion, shrinkage, and loss of color. A few good anatomical preparations might be used to show certain

peculiarities of structure (pl. CXXVII), or certain kinds of accessory material, such as sharks' and skates' eggs, for example, may add to the value of the exhibit.

A rare and interesting form like the goblin shark (*Mitsukurina owstoni*) might be shown, especially if placed beside a model of the living fish; but on the whole alcoholic specimens decidedly detract from the interest of the exhibit.

(2) *Mounted and painted skins* are sometimes effective for exhibit, especially with fish like the gar-pike (*Lepisosteus osseus*), the enameled scales of which are very successfully treated in this way. (Pl. CXXVIII.) In fact, this method may be used with many forms that have close-set, substantial scales (see yellow perch, pl. CXXIX), and is especially effective in a fish of either gaudy or dark colors (e. g., the angel-fish, or the groupers). It does not, however, effectually reproduce the smooth, gleaming, iridescent body of other fishes, as the shrinkage and hardening of the drying skin and the paint that is applied obscure the original quality of the surface. Hence, painting a skin practically amounts to nothing more than painting on an inferior surface.

(3) *Casts*, however, though but a reproduction, are faithful, if well executed, and furnish a surface much better adapted for coloring. Transparent colors over a metallic silver paint may be made to give the effects of iridescence, especially with such fish as the mackerels, pompanos, and the lookdown. But even the plaster cast, no matter how well painted, nevertheless does not perfectly succeed in giving the surface bloom of the living fish.

(4) *Models*.—Some fishes, especially the rarer forms, are hard to procure except as distorted alcoholic specimens, yet it may be desirable to represent them in the exhibit. In such cases, if sufficient data can be procured, a model may be constructed giving a restoration of the original and it may be well to exhibit the alcoholic specimen beside the model.

(5) *Skeletons*.—The exhibit may be varied and its value greatly increased by the use of mounted skeletons of typical forms. These may be correlated by appropriate labeling so as to bring out their chief differences.

(6) *Colored plates* taken from published works will add to the attractiveness of the exhibit and may be used to represent rare species which could not otherwise be shown. Many of these plates possess artistic beauty and represent the living fish better than any known method of artificial preparation. At the same time they portray the extraordinary variety of color and form possessed by the fishes of tropical seas. Some of these plates are shown in plate CXXX.

(7) *Groups*.—It is the pictorial group, however, that calls forth the greatest display of interest on the part of the visitor. Groups are the attractive feature, the drawing card of an exhibit. In bird and mammal collections they have been employed with great success. There are, however, comparatively few fish groups, and in these the mistake is often made of producing an aquarium

effect without a central point of interest. A fish or school of fish swimming among seaweed and rocks is not sufficient excuse for the time and expense incurred in producing a fish group. There must be a central idea or theme, such as the life history of some interesting species, an instance of peculiar breeding habits, or an illustration of some biological phenomenon, like adaptation, protective coloration, symbiosis, or sexual dimorphism, which can be emphasized in a descriptive label for the benefit of the visitor. Instead of being merely a spectacle, the group now has educational value; while it is the pictorial effect which at first arrests the attention of the observer, the lesson it has to teach is impressed on the mind more vividly than by any other method. (See appendix, p. 1340, for specific suggestions for these groups.)

The nature of a fish exhibit is such that no one kind of material should be used to the exclusion of the rest. To show to the best advantage it should be so arranged that casts are interspersed with mounted skins, skeletons, and colored plates, while the monotony of single specimens is broken by groups at judicious intervals.

METHODS OF ARRANGEMENT.

In general, the synoptic or systematic arrangement is the best to follow. This is most readily effected by using single specimens in the bulk of the exhibit, which should, however, be varied with groups and accessory exhibits of a faunistic, commercial, and biological character. The synoptic series has great teaching value for the student of elementary zoology, since the orderly grouping of fishes carries with it an orderly grouping of facts readily retained by the mind. It is true that many casual visitors may not appreciate the advantages of the system, but when well arranged it sets forth, rather than obscures, the attractive and striking forms. For the benefit of such visitors the individual labels are made clear, simple, and interesting, while those placed with the groups are particularly adapted to their requirements. The student, however, needs a classification that is more in line with his studies, and this is furnished by the synoptic method of arrangement.

The classification to be followed will vary of course according to individual judgment. The writer has found that a combination of the American system of Jordan and Evermann with the English system of Boulenger is best adapted for purposes of exhibition. Valuable help in this connection has been derived from W. K. Gregory's article on "The Orders of Teleostomous Fishes."[a] The scheme of classification will be given later in connection with the provisional list of fishes already referred to.

Three methods of arranging the exhibit in the hall are offered in the present paper, as follows: (1) the corridor arrangement; (2) the alcove arrangement; (3) the gallery arrangement.

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[a] Annals New York Academy of Sciences, vol. XVII, part II, no. 3, p. 437–508, pl. XXIX–XXX.

(1) *The corridor arrangement.*—This method is in use in the American Museum of Natural History, where the fish exhibit is at present placed in an L-shaped corridor (text fig. 1) connecting two wings of the museum. Here the cases are placed in end-to-end series along the walls on both sides, an arrangement well adapted for this style of hall. The cases for the synoptic series are of similar size and shape, of the variety shown in plate CXXVI. The two doors in front open outward. The back is solid and covered with a fabric (in this instance a blue denim), which sets off well the varied colors of the fishes. The specimens are attached directly to the back of the case and are removable. Nineteen cases are used at present for the synoptic series.

The main features of the arrangement and classification may be readily seen in the accompanying plates. The class Pisces is defined in a general label (pl. CXXXI) to be found at the entrance of the hall and also at intervals throughout the exhibit. Its subdivision into three subclasses is indicated at the bottom of the label. The parts of the hall devoted to the individual subclasses are shown by the large signs suspended from the ceiling (pl. CXXXII), while the orders are identified by

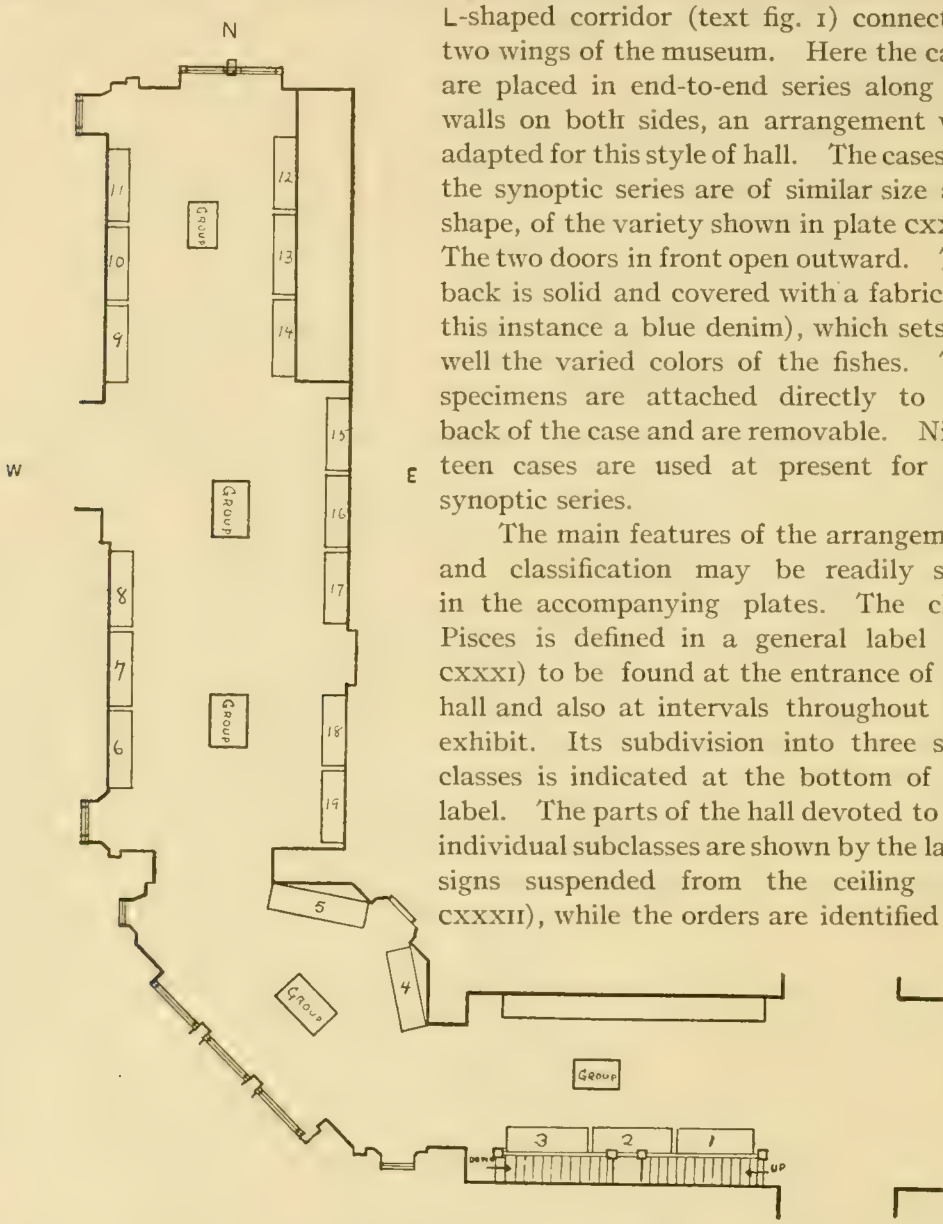


FIG. 1.—Plan of fish hall in the American Museum of Natural History, illustrating the "corridor method" of arranging the cases. The synoptic cases are numbered 1 to 19. The illustrative group cases are represented in the middle of the corridor.

small white-lettered boards at the top of each case (pl. CXXXIII). A case may contain as many as four or five suborders, or if many forms are shown, as in the Perciformes (pl. CXXX), or if the specimens are large, as in the Selachii (pl. CXXXV), two cases may be devoted to a single suborder. The location of each suborder is indicated by black lettering on the glass doors of the cases (pl. CXXXVI), and a definition of the group, together with a list of such of its included families as are represented in the exhibit, are found in descriptive case-labels hung on the doors of the cases (see pls. CXXXVI, CXXXVIII, and fig. 4, p. 1324).

The families are separated from each other by narrow bands of adhesive tape (pl. CXXXVII), harmonizing in color with the background, and are identified by small family-labels (text fig. 2) giving both the popular and scientific names and fastened to the back of the case in each family group. Under each specimen is a special descriptive label (text fig. 3) which gives the popular name

TROUTS

Family SALMONIDÆ

FIG. 2.—Example of family label.

in prominent type, while the scientific name is printed in smaller italic characters below. The name is followed by a brief popular description of the fish's habits, peculiarities, economic value, and geographical distribution. No effort, however, has been made to exhibit anything like a complete fish fauna, as the exhibit is entirely synoptic in character, only the principal families being shown and the typical and most interesting species in each family. Geographical distribution maps are being provided for the typical forms. Through the center of the hall will be placed groups illustrating life habits and other biological features. These will be of the general style shown in plate CXXXII. None are completed as yet, but in their places a few reptile groups have been installed temporarily.

The arrangement of the fish plates may be seen in plates CXXX, CXXXIII, CXXXIV, CXXXVI, and CXXXVII. They are mounted in passe-partout style and are hung to the backs of the cases in their proper synoptic position.

Very large and striking specimens are grouped in panels or friezes extending the length of the hall in the space between the ceiling and the tops of the cases (pl. CXXXVIII).

The labeling in this hall is based on the principle that since the exhibit has a double aim, being intended for both the general public and the students and instructors of the city schools and colleges, there should be a double system of labeling to meet the needs of the two classes. To this end the method of utilizing the exhibit by each class has been studied.

RAINBOW TROUT

Salmo irideus Gibbons

The so-called Rainbow Trout comprise several closely related species, and are noted for their gameness, dash, and beauty. They are found in mountain streams of the Pacific States and on the slopes of the Sierra Nevada Mountains. The typical Rainbow Trout (*Salmo irideus*) is found only in small brooks of the Californian Coast Ranges, and considering its size is perhaps the gamest of the series. It takes the fly with great readiness, even leaping from the water to meet it, and the struggle that follows is sure to be a long and keen one.

The weight of the Rainbow Trout varies from a half to 5 or 6 pounds, though the latter weight is exceptional.

FIG. 3.—Example of popular label for individual specimens.

The average person who enters the hall simply to see the exhibit is attracted first by the group cases. Then he passes before the synoptic cases, stopping here and there as his eye is attracted by some specimen. That is, it is the pictorial effect of the groups, or the striking features of some specimen, that draws his attention. In either case, if his interest is sufficiently aroused, he reads more or less of the accompanying label. Therefore the pictorial group labels and those with the individual specimens should be popular in character to meet his requirements (see fig. 3, p. 1322).

The elementary student of fishes, on the other hand, requires a systematic presentation of the subject, which will supplement and illustrate his studies.

To him the exhibit should appeal somewhat as an enlarged text-book, with object lessons for illustrations. It is to the elementary student, therefore, that the systematic arrangement is primarily directed—though it doubtless has its unconscious effect of orderliness upon the casual visitor as well—and the labels which bring out this classificatory side are aimed more directly at the student's understanding. Such are the labels indicating the larger groups, and especially the descriptive case labels defining the orders and suborders (see fig. 4, p. 1324). As these are based on anatomical features, especially those of the skeleton, they are necessarily more technical. An attempt, however, has been made to simplify them as much as possible, and to eliminate or explain technical terms. These labels also endeavor to bring out the phylogenetic relationship of the larger groups.

Accessory labels are freely used (fig. 5, p. 1325) to illustrate special features of biological interest.

(2) *The alcove arrangement.*—This is really an adaptation of the preceding method to a museum hall lighted by many windows from the side, thus permitting the cases to be placed alcove fashion with their ends to the windows, as in figure 6, page 1326. With this arrangement, instead of having a solid back, the cases are provided with glass on both sides, while a solid partition is constructed midway between, thus making it possible to utilize both sides of the case, in two adjoining alcoves.

The partition is covered with a colored fabric, e. g., blue denim, as in the preceding arrangement, and is framed in at top, bottom, and sides by light boards (fig. 7, p. 1327) inclined at an angle of about 45 degrees and wide enough to slant from the partition to the front edge of the case area, thus giving a beveled or countersunk effect. These inclined surfaces are covered with the same material as the partition and may be utilized for accessory labels, diagrams, etc. The bottom incline may also be utilized for such specimens as flatfishes, which would appear out of place when hung on a vertical surface.

THE TROUT-LIKE FISHES

Order MALACOPTERYGII

Suborder Isospondyli

Families

Elopidæ	*Clupeidæ*
Albulidæ	*Salmonidæ*
Mormyridæ	*Thymallidæ*

The fishes of this group include many of the most important food and game fishes, such as Tarpons, Trouts and Salmons, and the Herrings and Sardines. They are distinguished from the Ostariophysi (Case 6) by having the four anterior vertebræ of the spinal column unaltered and separate, and from the Eels (Apodes—Case 9) by the complete and well-developed skull. These characters, together with the soft-rayed dorsal fin and the cycloid scales—rounded in form and with smooth edges—also distinguish them from the Spiny-Rayed Fishes (Order Acanthopterygii—Case 9–14), most of which have ctenoid scales (i. e., scales rounded but with finely toothed edges) and fins partly supported by spines.

Like the Ostariophysi (Case 9) and the Pikes (Case 11) the Trouts have their ventral fins well separated from the pectorals and placed far back on the abdomen. This is a primitive arrangement and may be seen in all the lower fishes (e. g., the Sharks, Lungfishes, and Ganoids) and contrasts with the more specialized Acanthopterygian condition, in which the ventrals are attached close to the pectorals.

FIG. 4.—Example of descriptive case-label defining a suborder.

The fish in this case illustrate the natural phenomenon of degeneration, or rather specialization to an inactive life. The five suborders represented form a graded series of steps leading from fishes adapted to an extremely active existence down to relatively inactive, sluggish forms, incapable of rapid motion, but protected from their enemies by coats-of-mail or by the poisonous alkaloids in their flesh.

In the left-hand section may be seen the large, active wrasse-fishes and parrot-fishes (**Suborder PHARYNGOGNATHI**) well furnished with means of locomotion (i. e., fins), and with large gill-openings which permit the rapid oxygenation of the blood necessary to swiftly moving animals. The large cycloid scales are evenly distributed over the body and allow the greatest flexibility of movement. The teeth are adapted for seizing, and indicate carnivorous habits. Everything seems adapted to an extremely active life. On the other hand, there is a significant tendency toward fusion in certain bones of the skull, and (e. g., the parrot-fishes) in the teeth as well. This tendency is still more evident in the Scaly-Fin group (**Suborder SQUAMIPINNES**), where it appears in the fusion of the upper jaw elements, and in the gradual reduction of the gill-slits and the ventral fins. The body becomes laterally compressed and the transition to the type found in the next suborder (**SCLERODERMI**) is very clear. This suborder is represented in the upper right-hand section of this case by the trigger-fishes and file-fishes. Here the same flattened form is seen, and the reduction of the spinous dorsal and ventral fins to a few stiff spines is very evident. The bones of the skull have further fused, the gill-opening is a mere slit, and the upper jaw-teeth are compressed or even completely united, while the scales are reduced till, in the file-fishes, they become mere prickles. With the trunk-fishes (**Suborder OSTRACODERMI**) an immovable box-like armor takes the place of scales; the bones of the skull are almost completely joined; the gill-slit is extremely small; while the ribs and other skeletal elements have been practically reduced to a mere bony axis bracing the weak, soft dorsal, anal, and caudal fins. The spinous dorsal and the ventral fins have disappeared.

Finally, in the puffers (**Suborder GYMNODONTES**) we have the last stage of degeneration or specialization to a sluggish existence. Scales, spinous dorsal fin, and distinct teeth are gone. Pelvis, ribs, and caudal vertebræ are degenerate and, in extreme forms, even absent. The remaining fins, like those of the trunk-fish, are weak, and the body incapable of rapid motion, while the leathery skin, power of inflation, and poisonous flesh act as protective factors. The largest example of the group, the head-fish or mola, sluggishly floats on the surface of the sea, leading an inactive and lazy existence.

FIG. 5.—An accessory label to illustrate a biological phenomenon.

Each alcove should be devoted to one or two related subdivisions of fishes, arranged synoptically, as already described, and in the center of the alcove may

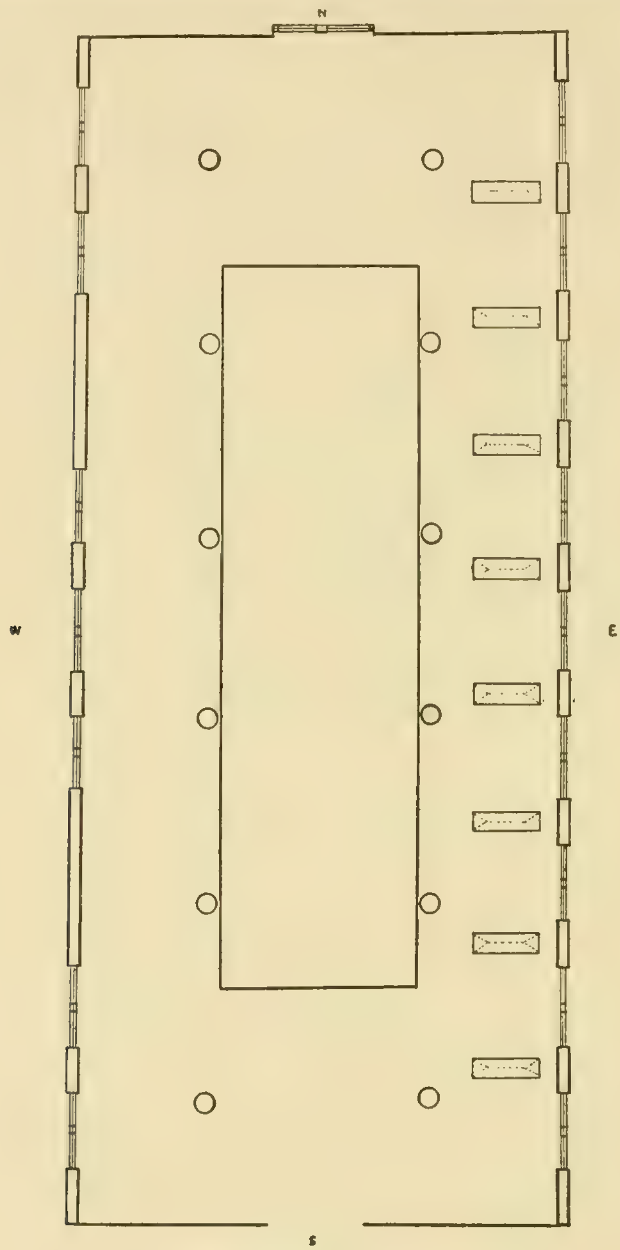


FIG. 6.—Plan showing hall adapted to the "alcove arrangement" of cases.

be placed a group case illustrating some features connected with one or more of the species in the surrounding cases.

(3) *The gallery arrangement.*—The idea for this somewhat more elaborate method was suggested by the gallery of habitat bird groups in the American Museum, but differs from it in that it combines a synoptic with a group exhibit. It is adapted for a gallery surrounding a hall occupying the space of two stories, such as occurs in most museums. At the side of the gallery farthest from the windows is a continuous screen to cut off all light from other parts of the hall (fig. 8, p. 1328), while the window side is entirely taken up with a series of exhibits, framed in by a casing, which, while it shuts off the light from the gallery, yet diverts it so as to illuminate the exhibit from within.

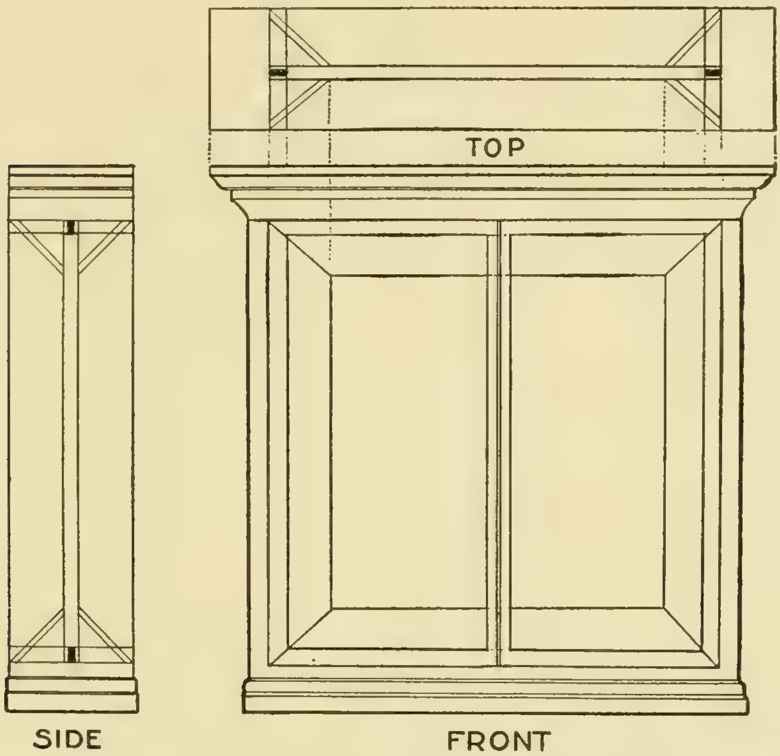


Fig. 7.—Diagram of fish case to be used in hall with "alcove arrangement," showing central partition with countersunk effect.

The adaptation of this method to a fish exhibit is shown in figure 9, page 1329. Through the opening (*A*) is seen a pictorial fish group representing some interesting feature. In the sketch an exhibit of fish life in the vicinity of a coral reef in tropical waters has been indicated in outline. This group is the central feature of that portion of the synoptic exhibit containing the suborders Pharyngognathi, Squamipinnes, Sclerodermi, and Gymnodontes, which contain so many of the brilliantly colored tropical species.

The panels *B* and *C* are devoted to the synoptic portion of the exhibit and contain representative species of the typical families included in the above-mentioned suborders. These specimens are fastened to a cloth-covered backing

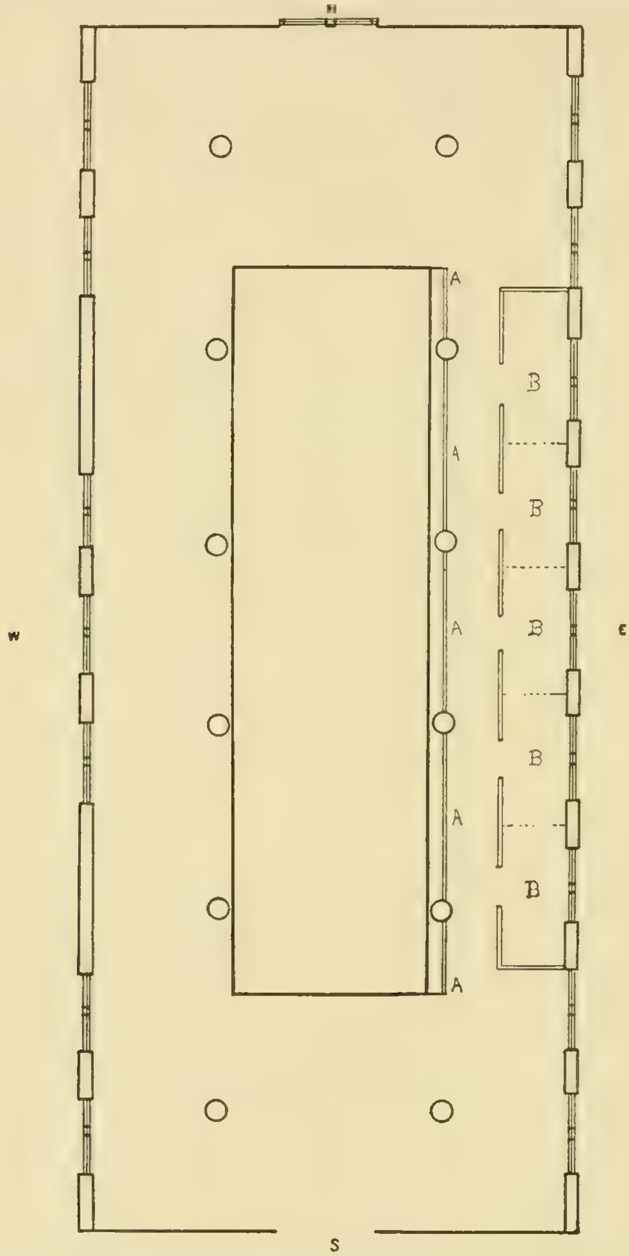


FIG. 8.—Plan illustrating the "gallery arrangement" of fish exhibits, showing screen (A) and row of group exhibits (B) of the kind shown in figure 9, page 1329.

placed just far enough behind the glass to comfortably accommodate the fish and show them off well. Small labels identify each specimen. The names of the suborders are lettered in black on the glass. The panels are lighted electric-

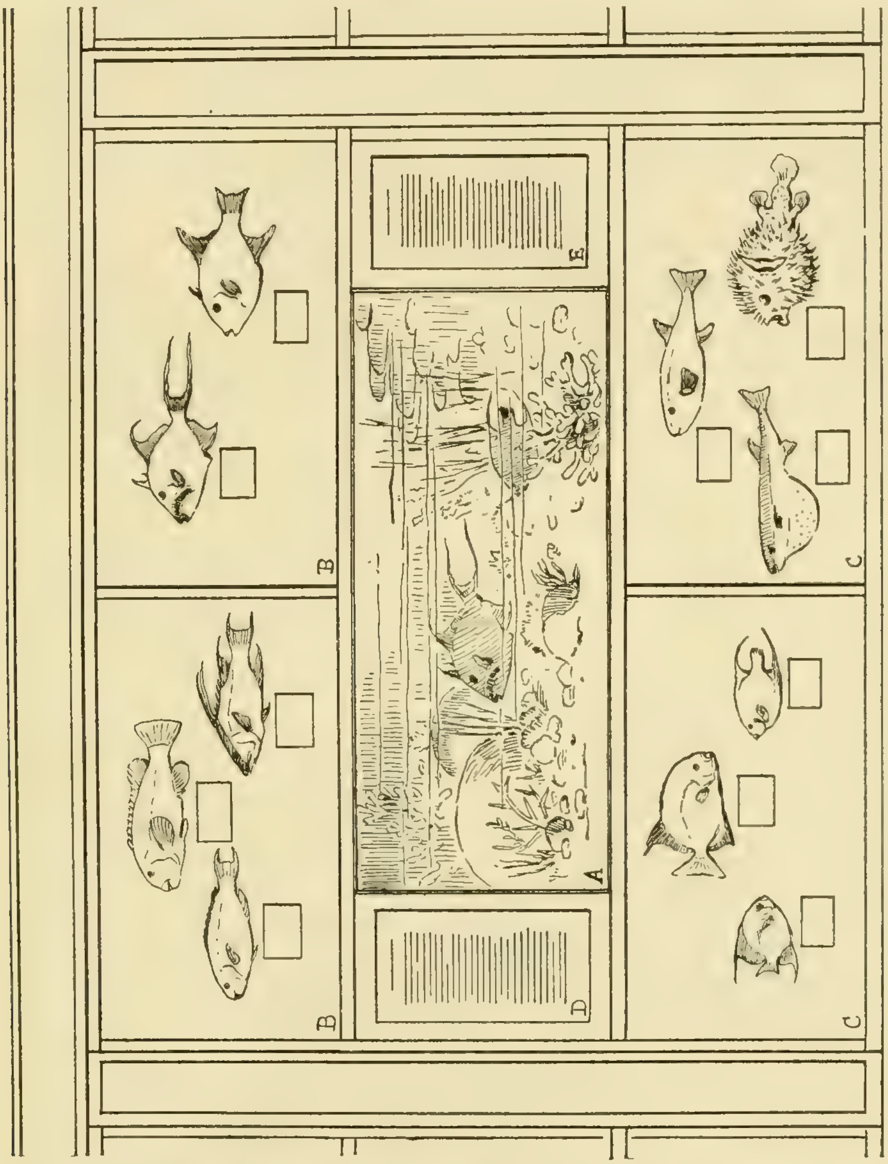


Fig. 9.—Sketch illustrating combination of pictorial fish groups with synoptic method of exhibition. (A) Group illuminated from within. (B, C) Panels devoted to synoptic portions of the exhibit. (D, E) Illuminated ground glass descriptive labels.

ally from above and below. At *D* and *E* are placed illuminated ground glass descriptive labels defining the synoptic divisions and describing the interesting features of the central group (*A*). The light from the windows behind may

be utilized to a large extent during the daytime for illuminating these exhibits with the help of properly arranged reflectors. Colored plates and photographs may be used to good effect on the walls of the hall at the ends of the gallery. (The two latter methods are offered as tentative suggestions for adapting to other museum conditions some of the ideas contained in method no. 1.)

SUPPLEMENTARY SUGGESTIONS.

(1) *Small fishes.*—Some species which should be represented in a synoptic series are so small that they would appear lost if placed directly against the case background. A good setting for such forms is shown in plate CXL. Here two specimens of *Hippocampus hudsonius* are mounted against a colored plaster panel, modeled in relief to give a suggestion of seaweed.

(2) *Small balanced aquaria* of living fishes may be used with good effect at or near the windows of the exhibition hall (pl. CXXXII). They may be either fresh water or marine, and forms may be exhibited from time to time that will be objects of interest in themselves. In such instances, small descriptive labels may be placed near the aquaria to bring out the interesting features. These labels should have removable backs to permit the insertion of new descriptive material as the fish exhibited are changed.

(3) *Colored plates* like those used in the synoptic series may be arranged in panels as wall decorations, as in plate CXXXII. These panels should harmonize with the general color scheme of the exhibit setting and may be devoted to the fauna of specific regions.

(4) *Photographs* of living fish, or illustrating the commercial fisheries, etc., may be used to add interest and attractiveness to the halls.

(5) A *plan* of the hall should be placed at the entrance to aid the visitor in orienting himself and in finding groups of which he may be in search.

(6) Many of the descriptive labels may be effectively illustrated either by indexed outline drawings for the sake of added clearness (pl. CXXXI) or by water-color sketches illustrating interesting habits (pl. CXXXIX).

(7) A *special exhibit* of the fishes most abundant locally could be made an attractive feature, or this could be arranged as a seasonal exhibit by changing the fishes to correspond with their seasonal abundance in local waters.

(8) Single specimens may sometimes be artistically mounted on a pedestal, with just a suggestion of accessory setting, as in plate CXLI.

PROVISIONAL LIST OF FISHES FOR A SYNOPTIC EXHIBIT.

In the following list selection has been made from species which would fall under the five following classes: (1) Typical forms; (2) commercial forms; (3) peculiar and striking forms; (4) forms with interesting life-habits; (5) forms valuable for illustrating biological phenomena like protective coloration, symbi-

osis, adaptation, etc. Only a tentative selection is given, and many of the species named could be replaced by other forms.

The classification used in the list, as above mentioned, is a combination of the English and American systems, adapted for exhibition purposes.

It is natural that particular emphasis should be laid on North American fishes, and these are chosen to represent the families where possible. More room is also given to commercial fishes than to others.

CLASS PISCES.

Subclass Elasmobranchii.

ORDER PLAGIOSTOMI.

- Suborder Selachii.
  - Family Notidanidæ.
    - *Notidanus* (*Hexanchus*) *griseus* (cow shark).
  - Family Scylliidæ.
    - *Ginglymostoma cirratum* (nurse shark).
  - Family Galeidæ.
    - *Mustelus canis* (dog shark).
    - *Carcharinus lamia* (cub shark).
  - Family Carchariidæ.
    - *Carcharias littoralis* (sand shark).
    - *Prionace glauca* (great blue shark).
    - *Scoliodon terræ-novæ* (sharp-nosed shark).
  - Family Sphyrnidæ.
    - *Sphyrna zygæna* (hammer-head shark).
    - *Sphyrna tiburo* (bonnet-head shark).
  - Family Alopiidæ.
    - *Alopias vulpes* (thresher shark).
  - Family Lamnidæ.
    - *Carcharodon carcharias* (man-eater shark).
    - *Lamna cornubica* (porbeagle).
  - Family Cetorhinidæ.
    - *Cetorhinus maximus* (basking shark).
  - Family Squalidæ.
    - *Squalus acanthias* (dogfish).
  - Family Rhinidæ.
    - *Rhina squatina* (angel shark).
- Suborder Batoidei.
  - Family Pristidæ.
    - *Pristis pectinatus* (common sawfish).
  - Family Rhinobatidæ.
    - *Rhinobatus lentiginosus* (guitar-fish).
  - Family Raiidæ.
    - *Raia erinacea* (common skate).
    - *Raia lævis* (barndoor skate).
  - Family Torpedinidæ.
    - *Tetronarce occidentalis* (torpedo).
  - Family Dasyatidæ.
    - *Dasyatis centrura* (sting ray).
  - Family Myliobatidæ.
    - *Myliobatis freminvillei* (eagle ray).
    - *Manta birostris* (sea devil).

ORDER HOLOCEPHALI.

Suborder Chimæroidei.

Family Chimæridæ.

Chimæra monstrosa (chimæra).
Chimæra colliei (ratfish).
Chimæra purpurascens (purple chimæra).

SUBCLASS DIPNEUSTI.

ORDER MONOPNEUMONA.

Family Ceratodontidæ.

Neoceratodus forsteri (Australian lungfish).

ORDER DIPLOPNEUMONA.

Family Lepidosirenidæ.

Protopterus dolloi (African lungfish).
Protopterus annectens (African lungfish).
Protopterus æthiopicus (African lungfish).
Lepidosiren paradoxa (South American lungfish).

SUBCLASS TELEOSTOMI.

ORDER CROSSOPTERYGII.

Suborder Cladistia.

Family Polypteridæ.

Polypterus bichir (bichir).

ORDER CHONDROSTEI.

Family Polyodontidæ.

Polyodon spathula (paddlefish).

Family Acipenseridæ.

Acipenser sturio (common sturgeon).
Acipenser rubicundus (lake sturgeon).
Scaphirhynchus platyrhynchus (shovel-nose sturgeon).

ORDER HOLOSTEI.

Suborder Rhomboganoidea.

Family Lepisosteidæ.

Lepisosteus osseus (long-nose gar).
Lepisosteus platostomus (short-nose gar).
Lepisosteus tristæchus (alligator gar).

Suborder Cycloganoidea.

Family Amiidæ.

Amia calva (bowfin).

ORDER OSTARIOPHYSI.

Suborder Nematognathi.

Family Siluridæ.

Ameiurus catus (white cat).
Felichthys marinus (gaff-topsail).
Ictalurus punctatus (channel cat).
Ameiurus nebulosus (common bullhead).
Schilbeodes insignis (mad tom).

Suborder Eventognathi.

Family Catostomidæ.

Catostomus commersonii (common sucker).

Family Cyprinidæ.

Moxostoma aureolum (common redhorse).
Ictiobus cyprinella (red-mouth buffalo-fish).

ORDER OSTARIOPHYSI—continued.

Suborder Eventognathi—Continued.

Family Cyprinidæ—Continued.

Cyprinus carpio (golden carp).
Campostoma anomalum (stone roller).
Semotilus atromaculatus (horned dace).
Notropis sp. (shiner).
Rhinichthys atronasus (black-nose dace).

Suborder Heterognathi.

Family Erythrinidæ.

Macrodon microlepis (trahira).

Family Characinidæ.

Brycon dentex (characin).
Hydrocyon goliath (characin).
Tetragonopterus argentatus (sardina blanca).

Suborder Gymnonoti.

Family Gymnotidæ.

Giton fasciatus (carapo).
Gymnotus electricus (electric eel).

ORDER APODES.

Suborder Colocephali.

Family Murænidæ.

Lycodontis moringa (common spotted moray).
Lycodontis ocellatus (spotted moray).
Lycodontis funebris (black moray).
Muræna retifera (moray).
Echidna nebulosa (moray).

Suborder Enchelycephali.

Family Anguillidæ.

Anguilla chrysypa (American eel).

Family Leptocephalidæ.

Leptocephalus conger (conger eel).

Family Nemichthyidæ.

Nemichthys scolopæus (snipe eel).

Family Myridæ.

Myrophis punctatus (worm eel).

Family Ophichthyidæ.

Ophichthys gomesii (sea serpent).

ORDER MALACOPTERYGII.

Suborder Isospondyli.

Family Elopidæ.

Tarpon atlanticus (tarpon).
Elops saurus (ten-pounder).

Family Albulidæ.

Albula vulpes (ladyfish).

Family Hiodontidæ.

Hiodon tergisus (moon-eye).

Family Clupeidæ.

Clupea harengus (common herring).
Alosa sapidissima (American shad).
Pomolobus pseudoharengus (alewife).
Brevoortia tyrannus (menhaden).

ORDER MALACOPTERYGII—continued.

Suborder Isospondyli—Continued.

Family Salmonidæ.

Coregonus clupeiformis (common whitefish).
Oncorhynchus tschawytscha (quinnat salmon).
Salmo irideus (rainbow trout).
Salmo sebago (landlocked salmon).
Salmo salar (common Atlantic salmon).
Salvelinus fontinalis (brook trout).
Cristivomer namaycush (Mackinaw trout).

Family Thymallidæ.

Thymallus ontariensis (Michigan grayling).

Family Argentinidæ.

Osmerus mordax (American smelt).

ORDER MESICHTHYES.

Suborder Haplomi.

Family Synodontidæ.

Synodus varius (lizard-fish).
Synodus fœtens (lizard-fish).

Family Ipnopidæ.

Ipnops murrayi (lantern-eye).

Family Dalliidæ.

Dallia pectoralis (Alaska blackfish).

Family Esocidæ.

Umbra pygmæa (eastern mud minnow).
Esox masquinongy (muskallunge).
Esox reticulatus (pickerel).

Family Pœciliidæ.

Fundulus heteroclitus (common killifish).
Cyprinodon variegatus (sheepshead minnow).
Anableps dovii (four-eyed fish).
Heterandria formosa.

Family Amblyopsidæ.

Typhlichthys subterraneus (small blindfish).
Amblyopsis spelæus (blindfish of Mammoth Cave).

Suborder Synentognathi.

Family Belonidæ.

Tylosurus caribbæus (needlefish).

Family Hemirhamphidæ.

Hyporhamphus roberti (common half-beak).
Scombresox saurus (saury).

Family Exocœtidæ.

Fodiator acutus (sharp-nose flying-fish).
Exocœtus volitans (flying-fish).

ORDER THORACOSTRACI.

Suborder Hemibranchii.

Family Gasterosteidæ.

Gasterosteus bispinosus (common eastern stickleback).
Gasterosteus aculeatus (European stickleback).

Family Fistulariidæ.

Fistularia tabacaria (trumpet-fish).

ORDER THORACOSTRACI—continued.

Suborder Lophobranchii.

Family Syngnathidæ.

Siphostoma fuscum (common pipefish).
Hippocampus hudsonius (common sea-horse).
Hippocampus stylifer (sea-horse).
Hippocampus punctulatus (caballeto de mar).
Hippocampus zosteræ (sea-horse).

ORDER ACANTHOPTERYGII.

Suborder Percesoces.

Family Atherinidæ.

Menidia gracilis (silverside).

Family Mugilidæ.

Mugil cephalus (common mullet).
Mugil curema (white mullet).

Family Sphyrænidæ.

Sphyræna borealis (northern barracuda).

Family Mullidæ.

Upeneus maculatus (red goatfish).
Upeneus martinicus (yellow goatfish).

Family Holocentridæ.

Holocentrus ascensionis (squirrel-fish).

Family Ammodytidæ.

Ammodytes americanus (sand launce).

Suborder Scombriformes.

Family Scombridæ.

Gymnosarda pelamis (oceanic bonito).
Thunnus thynnus (tunny).
Scomber scombrus (common mackerel).
Sarda sarda (bonito).
Scomberomorus maculatus (Spanish mackerel).

Family Trichiuridæ.

Trichiurus lepturus (cutlass-fish).

Family Istiophoridæ.

Istiophorus nigricans (sailfish).

Family Xiphiidæ.

Xiphias gladius (common swordfish).

Family Carangidæ.

Oligoplites saurus (leather-jacket).
Caranx hippos (crevallé).
Caranx crysos (runner).
Vomer setipennis (moonfish).
Selene vomer (lookdown).
Trachinotus goodei (great pompano).
Trachinotus carolinus (common pompano).

Family Pomatomidæ.

Pomatomus saltatrix (bluefish).

Family Coryphænidæ.

Coryphæna hippurus (common dolphin).

Family Stromateidæ.

Poronotus triacanthus (butterfish).

Family Rachycentridæ.

Rachycentron canadum (sergeant-fish).

ORDER ACANTHOPTERYGII—continued.

Suborder Perciformes.

Family Centrarchidæ.

Centrarchus macropterus (round sunfish).
Lepomis auritus (redbreast bream).
Lepomis pallidus (blue-gill).

Family Percidæ.

Stizostedion canadense (sauger).
Perca flavescens (yellow perch).
Ammocrypta pellucida (sand darter).

Family Serranidæ.

Roccus chrysops (white bass).
Roccus lineatus (striped bass).
Morone americana (white perch).
Bodianus fulvus punctatus (nigger-fish).
Epinephelus striatus (Nassau grouper).
Epinephelus adscensionis (rock hind).
Epinephelus guttatus (red hind).
Epinephelus morio (red grouper).
Garrupa nigrita (black jewfish).
Centropristes striatus (black sea bass).

Family Priacanthidæ.

Priacanthus arenatus (catalufa).

Family Lutianidæ.

Neomænis griseus (gray snapper).
Neomænis guttatus (flamenco).
Neomænis jocu (dog snapper).
Neomænis apodus (schoolmaster).
Lutianus aya (red snapper).
Lutianus analis (mutton-fish).
Ocyurus chrysurus (yellow-tail).

Family Hæmulidæ.

Hæmulon album (margate-fish).
Hæmulon plumieri (common grunt).
Bathystoma rimator (red-mouth grunt).
Orthopristis chrysopterus (hogfish).

Family Sparidæ.

Calamus bajonado (jolt-head porgy).
Stenotomus chrysops (common scup).
Archosargus probatocephalus (sheepshead).
Archosargus unimaculatus (salema).

Family Gerridæ.

Gerres olisthostomus (Irish pompano).

Family Sciænidæ.

Cynoscion regalis (common weakfish).
Cynoscion nebulosus (spotted weakfish).
Bairdiella chrysura (mademoiselle).
Sciænops ocellatus (channel bass).
Micropogon undulatus (croaker).
Menticirrhus americanus (Carolina whiting).
Menticirrhus saxatilis (kingfish).
Pogonias cromis (drum).
Aplodinotus grunniens (freshwater drum).

ORDER ACANTHOPTERYGII—continued.
Suborder Perciformes—Continued.
Family Pomacentridæ.
Eupomacentrus leucostictus (Beau Gregory).
Eupomacentrus fuscus (Maria Molle).
Abudefduf saxatilis (cow pilot).
Suborder Pharyngognathi.
Family Labridæ.
Tautogolabrus adspersus (cunner).
Tautoga onitis (tautog).
Lachnolaimus maximus (hogfish).
Halichœres sp.
Family Scaridæ.
Sparisoma abildgaardi (red parrot-fish).
Callyodon cœruleus (blue parrot-fish).
Scarus vetula (old wife).
Suborder Squamipinnes.
Family Ephippidæ.
Chætodipterus faber (spade-fish).
Family Chætodontidæ.
Megaprotodon trifascialis.
Pomacanthus arcuatus (black angel).
Holacanthus tricolor (rock beauty).
Holacanthus ciliaris (blue angel-fish).
Chætodon ocellatus (isabelita).
Chætodon capistratus (parché).
Chætodon striatus (butterfly-fish).
Suborder Sclerodermi.
Family Balistidæ.
Balistes vetula (old wife).
Balistes carolinensis (leather-jacket).
Balistapus rectangulus.
Family Teuthididæ.
Teuthis cœruleus (blue tang).
Teuthis hepatus (common surgeon-fish).
Family Monacanthidæ.
Monacanthus hispidus (filefish).
Alutera schœpfi (orange filefish).
Suborder Ostracodermi.
Family Ostraciidæ.
Lactophrys trigonus (common trunkfish).
Lactophrys bicaudalis (spotted trunkfish).
Lactophrys triqueter (rock shellfish).
Lactophrys tricornis (cowfish).
Suborder Gymnodontes.
Family Tetraodontidæ.
Lagocephalus lævigatus (smooth puffer).
Spheroides maculatus (puffer).
Family Diodontidæ.
Diodon hystrix (porcupine-fish).
Chilomycterus schœpfi (common burrfish).
Family Molidæ.
Mola mola (ocean sunfish).

ORDER ACANTHOPTERYGII—continued.
- Suborder Scleroparei.
  - Family Scorpænidæ.
    - *Sebastes marinus* (rosefish).
    - *Sebastodes constellatus* (spotted rockfish).
    - *Sebastodes rosaceus* (corsair).
  - Family Cottidæ.
    - *Cottus ictalops* (miller's-thumb).
    - *Myoxocephalus octodecimspinosus* (long-spined sculpin).
    - *Hemitriperus americanus* (sea-raven).
  - Family Triglidæ.
    - *Prionotus carolinus* (common gurnard).
    - *Prionotus strigatus* (northern striped gurnard).
  - Family Cephalacanthidæ.
    - *Cephalacanthus volitans* (flying robin).
  - Family Cyclopteridæ.
    - *Cyclopterus lumpus* (lumpfish).
  - Family Liparididæ.
    - *Liparis liparis* (sea-snail).
- Suborder Gobiiformes.
  - Family Gobiidæ.
    - *Dormitator maculatus* (pañeca).
    - *Gobius oceanicus* (esmeralda).
    - *Typhlogobius californiensis* (blind goby).
- Suborder Discocephali.
  - Family Echeneididæ.
    - *Echeneis naucrates* (shark-sucker).
    - *Remora remora* (remora).
- Suborder Jugulares.
  - Family Malacanthidæ.
    - *Malacanthus plumieri* (matajuelo blanco).
    - *Caulolatilus princeps* (blanquillo).
    - *Lopholatilus chamæleonticeps* (tilefish).
  - Family Uranoscopidæ.
    - *Astroscopus y-græcum* (electric stargazer).
  - Family Batrachoididæ.
    - *Opsanus tau* (toadfish).
    - *Porichthys notatus* (singing-fish).
  - Family Gobiesocidæ.
    - *Gobiesox virgatulus* (clingfish).
  - Family Blenniidæ.
    - *Pholis gunnellus* (butterfish).
    - *Lumpenus lampetræformis* (snake blenny).
    - *Labrisomus nuchipennis.*
  - Family Anarhichadidæ.
    - *Cryptacanthodes maculatus* (wry-mouth).
    - *Anarhichas lupus* (wolf-fish).
  - Family Zoarcidæ.
    - *Zoarces anguillaris* (eel pout).
  - Family Fierasferidæ.
    - *Fierasfer affinis* (pearlfish).

ORDER ACANTHOPTERYGII—continued.
Suborder Tæniosomi.
Family Regalecidæ.
Regalecus glesne (oarfish).[a]
Family Trachypteridæ.
Trachypterus rex-salmonorum (king-of-the-salmon).[a]
Suborder Anacanthini.
Family Merlucciidæ.
Merluccius merluccius (European hake).
Merluccius bilinearis (whiting).
Family Gadidæ.
Gadus callarias (common cod).
Microgadus tomcod (tomcod).
Pollachius virens (pollock).
Melanogrammus æglefinus (haddock).
Lota maculosa (burbot).
Molva molva (ling).
Urophycis tenuis (squirrel hake).
Enchelyopus cimbrius (four-bearded rockling).
Brosme brosme (cusk).
Family Macrouridæ.
Macrourus bairdii (common rat-tail).
Suborder Heterosomata.
Family Pleuronectidæ.
Hippoglossus hippoglossus (halibut).
Paralichthys dentatus (summer flounder).
Paralichthys oblongus (four-spotted flounder).
Limanda ferruginea (rusty dab).
Pseudopleuronectes americanus (winter flounder).
Hippoglossoides platessoides (sand dab).
Lophopsetta maculata (window-pane).
Family Soleidæ.
Achirus fasciatus (American sole).
Symphurus plagusia (tongue-fish).
ORDER PEDICULATI.
Family Lophiidæ.
Lophius piscatorius (common angler).
Family Ceratiidæ.
Cryptopsaras couesii (sea-devil).
Family Antennariidæ.
Pterophryne histrio (sargassum-fish).
Antennarius ocellatus (frogfish).
Family Malthidæ.
Ogcocephalus vespertilio (batfish).
Malthe malthe.

[a] Rare. To be represented by colored plates or drawings.

APPENDIX.

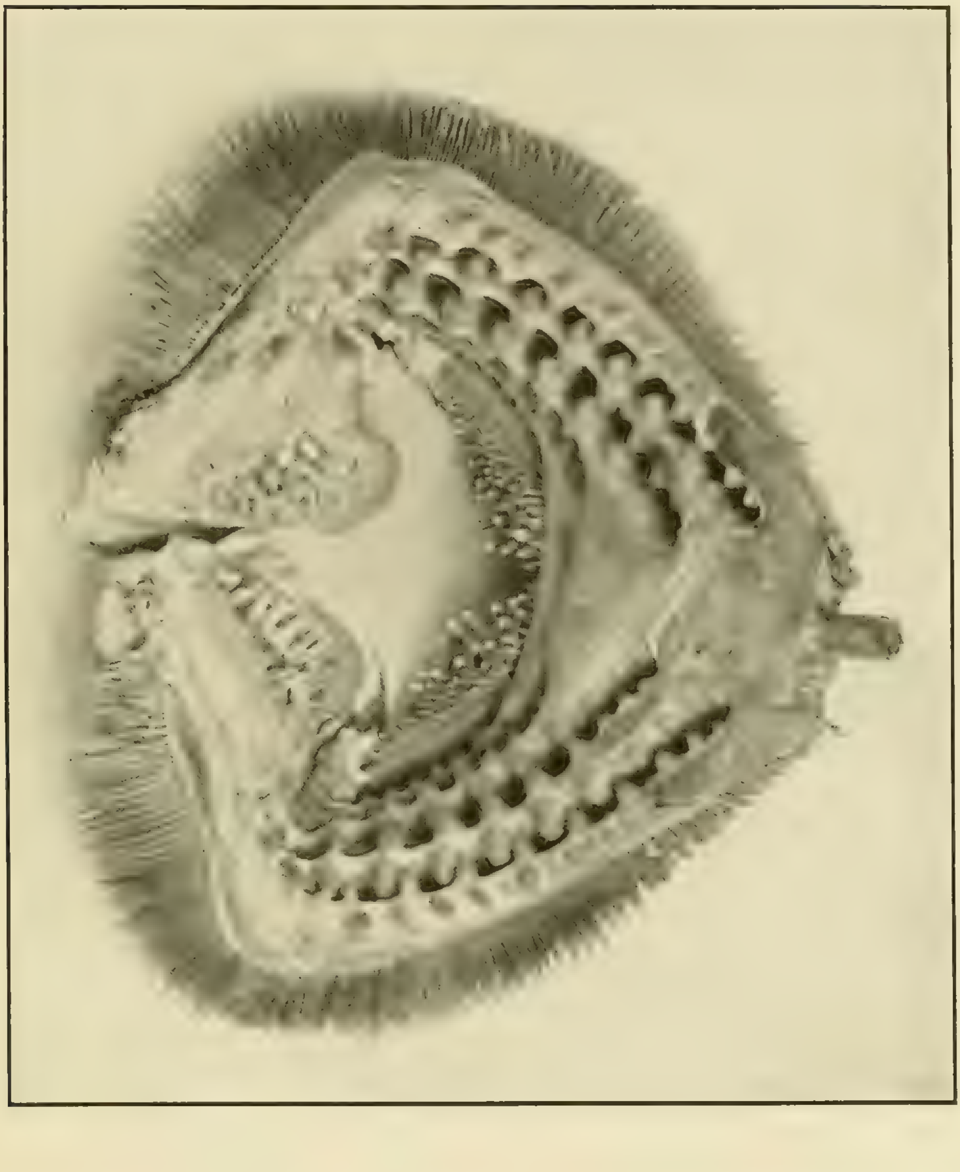
SUGGESTIONS FOR SUBJECTS FOR ILLUSTRATIVE MUSEUM FISH GROUPS.

(See pages 1318–1319.)

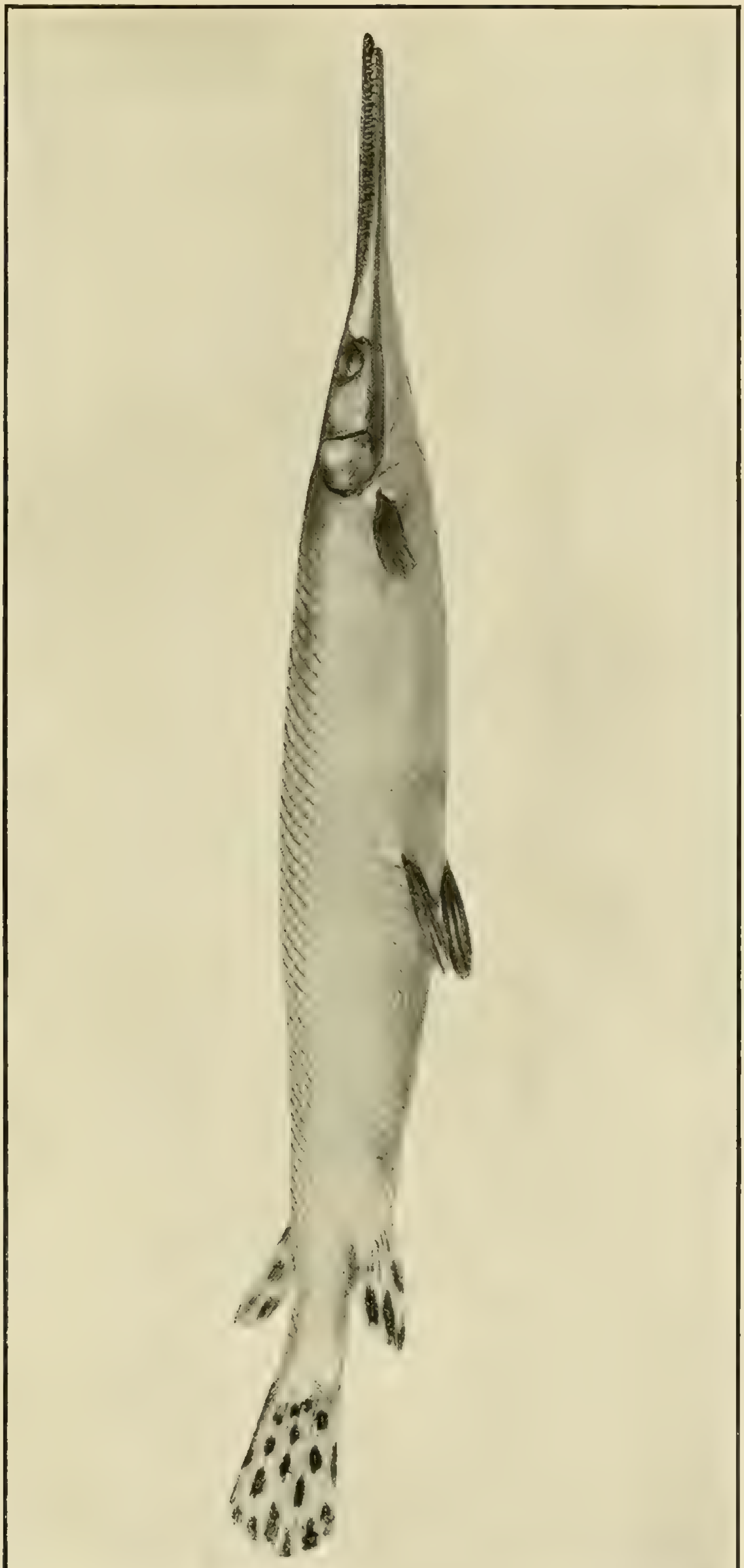
Order Plagiostomi: Cub-shark with shark-sucker. (Commensalism.)
Transitional forms—shark to skate. (Evolution and adaptation.)
Order Holocephali: Life history of *Chimæra colliei.* (Growth and development.)
Subclass Dipneusti: Nesting and burrowing habits of *Protopterus.*
Order Chondrostei: Feeding habits of *Polyodon spathula.* (Also adaptation.)
Order Holostei: Nesting and feeding habits of *Amia calva.* (Instincts.)
Order Ostariophysi: Land habits of *Doras.* (Possible evolution in progress.)
Order Apodes: Life history of the common eel. (Metamorphosis.)
Group of morays. (Adaptation.)
Deep sea saccopharyngids. (Adaptation.)
Order Malacopterygii: Humpbacked or hooknosed salmon. (Sexual dimorphism.)
Salmon leaping. (Instincts.)
Order Mesichthyes: Four-eyed fish (*Anableps dovii*). (Adaptation.)
Blindfish—cave fauna. (Degeneration; adaptation.)
Group of flying fishes. (Adaptation.)
Order Thoracostraci: Breeding habits of stickleback. (Instincts.)
Group of sea horses. (Specialization; protective resemblance.)
Order Acanthopterygii:
Suborder Percesoces: Habits and adaptations of *Anabas scandens.*
Suborder Scombriformes: Life history of *Selene vomer.* (Metamorphosis.)
Nomeus gronovii and *Physalia arcthusa.* (Symbiosis.)
Suborder Perciformes: Nesting habits of the gourami (*Osphromenus olfax*). (Instincts.)
Suborders Perciformes, Pharyngognathi, Squamipinnes, Sclerodermi, and Gymnodontes: Tropical coloration and degeneration.
Suborder Scleroparei: Group of toadfishes, sea-robins and sea-ravens to illustrate adaptation to bottom life and protective resemblance.
Suborder Jugulares: Group of *Fierasfer acus* and holothurians to illustrate symbiosis.
Suborder Heterosomata: Life history of flounder. (Metamorphosis, adaptation to bottom life, and protective resemblance.)
Order Pediculati: Group of deep-sea fishes illustrating adaptation.

NOTE.—In several instances two or more of the above suggestions could be advantageously combined in a single group, illustrating several biological principles in one exhibit.

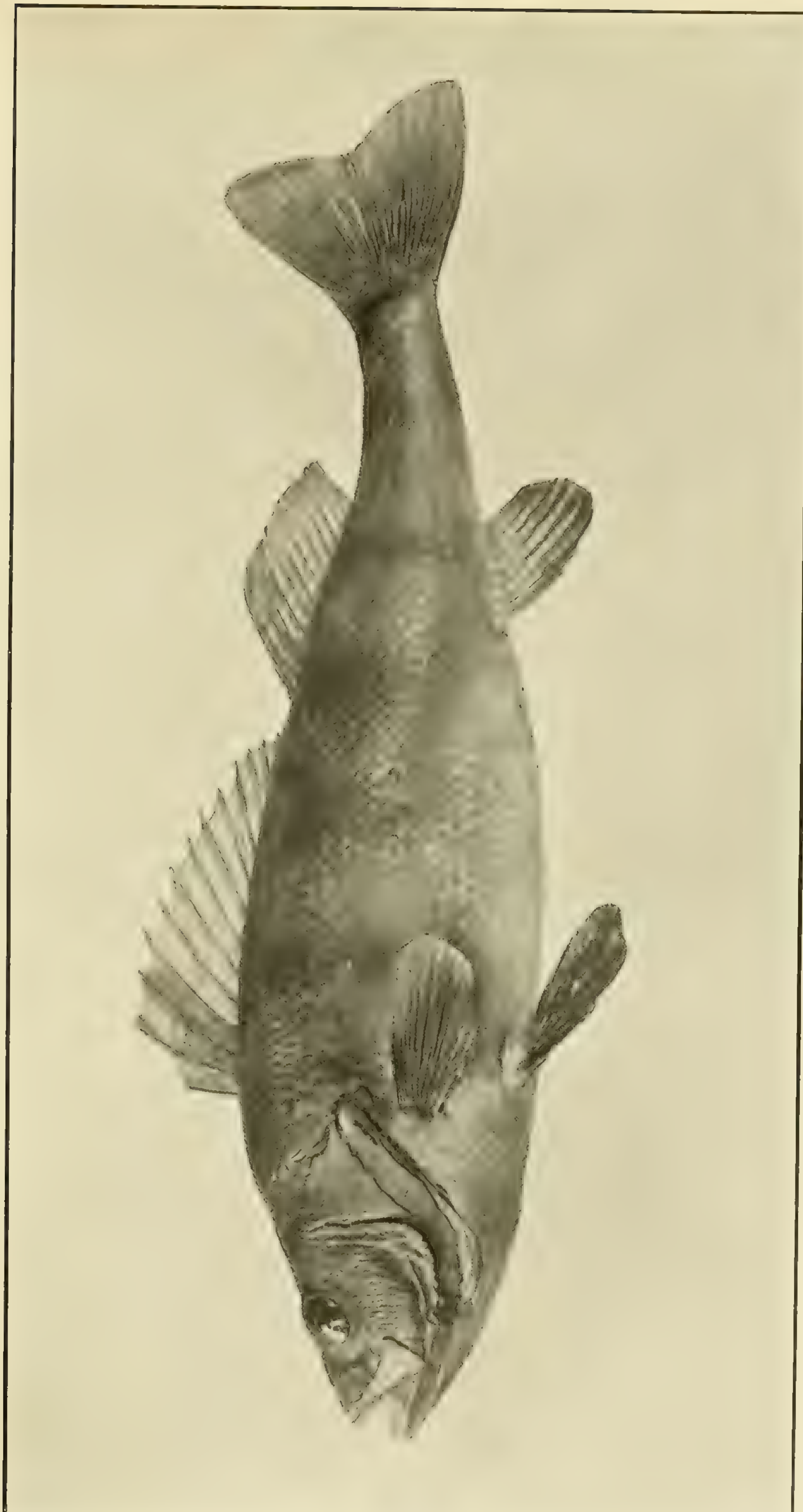
Typical synoptic case used in "corridor arrangement" for exhibition of fishes.



Section showing gill arches and pharyngeal teeth of the channel bass (*Sciænops ocellatus*). This illustrates the kind of alcoholic material to be used as accessory anatomical exhibits.

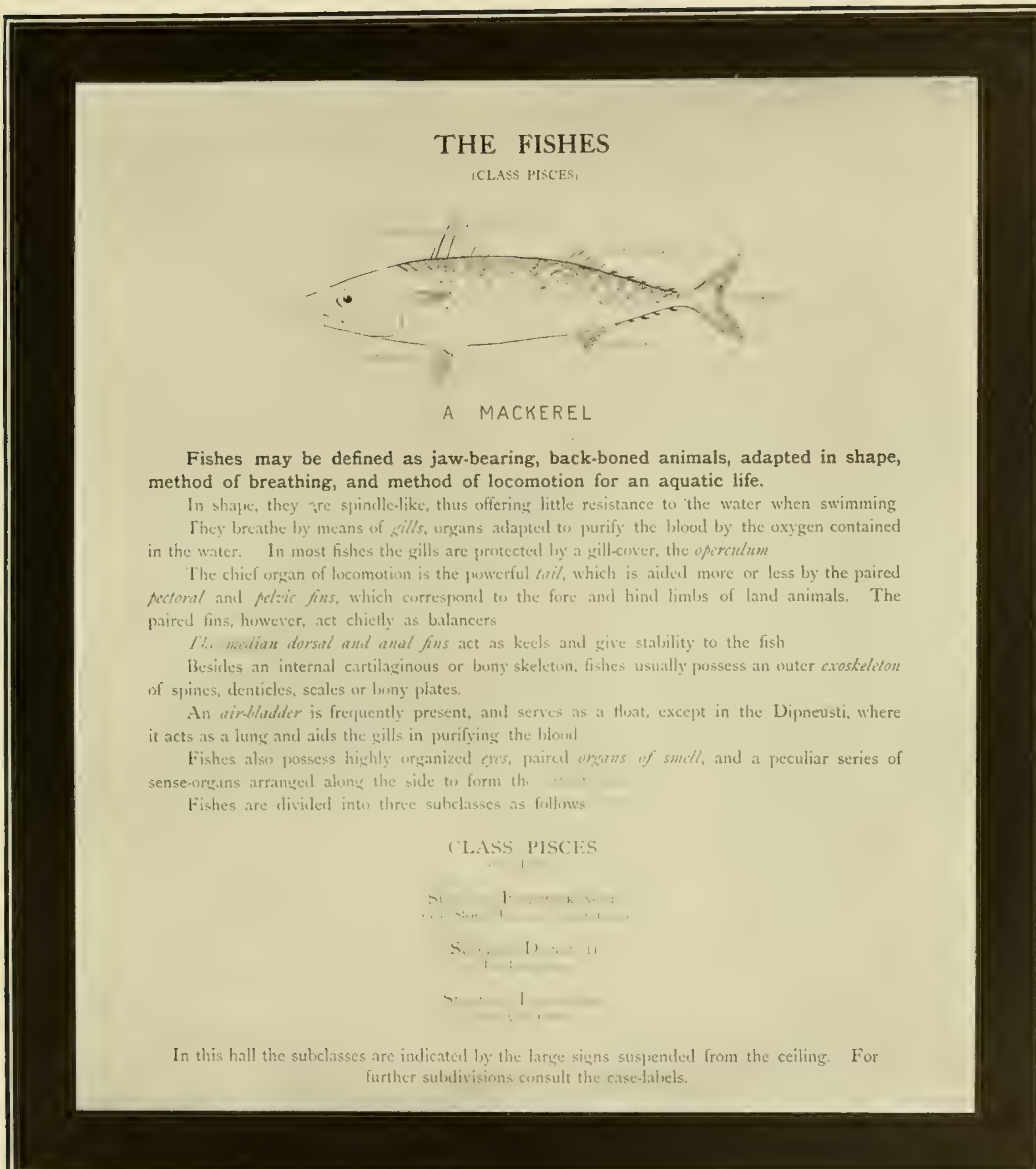


Mounted and painted skin of the long-nosed gar (*Lepisosteus osseus*), the hard enameled scales of which may be advantageously treated in this way.



Mounted and painted skin of yellow perch (*Perca flavescens*).

One of the cases devoted to the perch group, showing methods of utilizing colored plates and labels.



THE FISHES

(CLASS PISCES)

A MACKEREL

Fishes may be defined as jaw-bearing, back-boned animals, adapted in shape, method of breathing, and method of locomotion for an aquatic life.

In shape, they are spindle-like, thus offering little resistance to the water when swimming

They breathe by means of *gills*, organs adapted to purify the blood by the oxygen contained in the water. In most fishes the gills are protected by a gill-cover, the *operculum*

The chief organ of locomotion is the powerful *tail*, which is aided more or less by the paired *pectoral* and *pelvic fins*, which correspond to the fore and hind limbs of land animals. The paired fins, however, act chiefly as balancers

The median dorsal and anal fins act as keels and give stability to the fish

Besides an internal cartilaginous or bony skeleton, fishes usually possess an outer *exoskeleton* of spines, denticles, scales or bony plates.

An *air-bladder* is frequently present, and serves as a float, except in the Dipneusti, where it acts as a lung and aids the gills in purifying the blood

Fishes also possess highly organized *eyes*, paired *organs of smell*, and a peculiar series of sense-organs arranged along the side to form the [illegible]

Fishes are divided into three subclasses as follows

CLASS PISCES

[illegible]

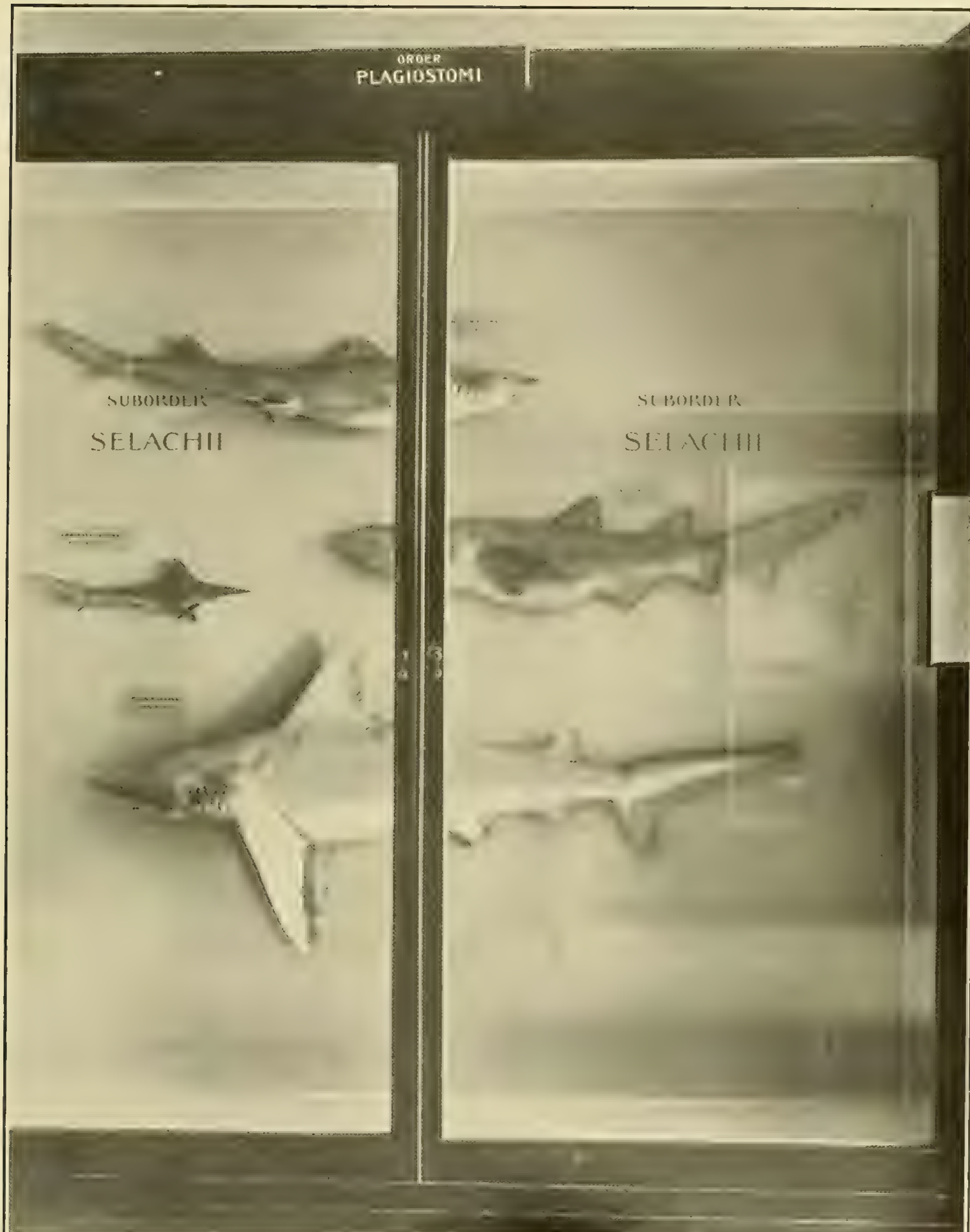
In this hall the subclasses are indicated by the large signs suspended from the ceiling. For further subdivisions consult the case-labels.

General label defining class Pisces. Framed copies of this label are placed in various parts of the fish hall. The figure of the mackerel at the top is drawn in by hand. A different species is represented on each copy of the label, corresponding to the fish forms near which it is placed.

A corner in the fish corridor, showing the subclass signs suspended from the ceiling, the use of aquaria, and colored plates in panels for decorative purposes.

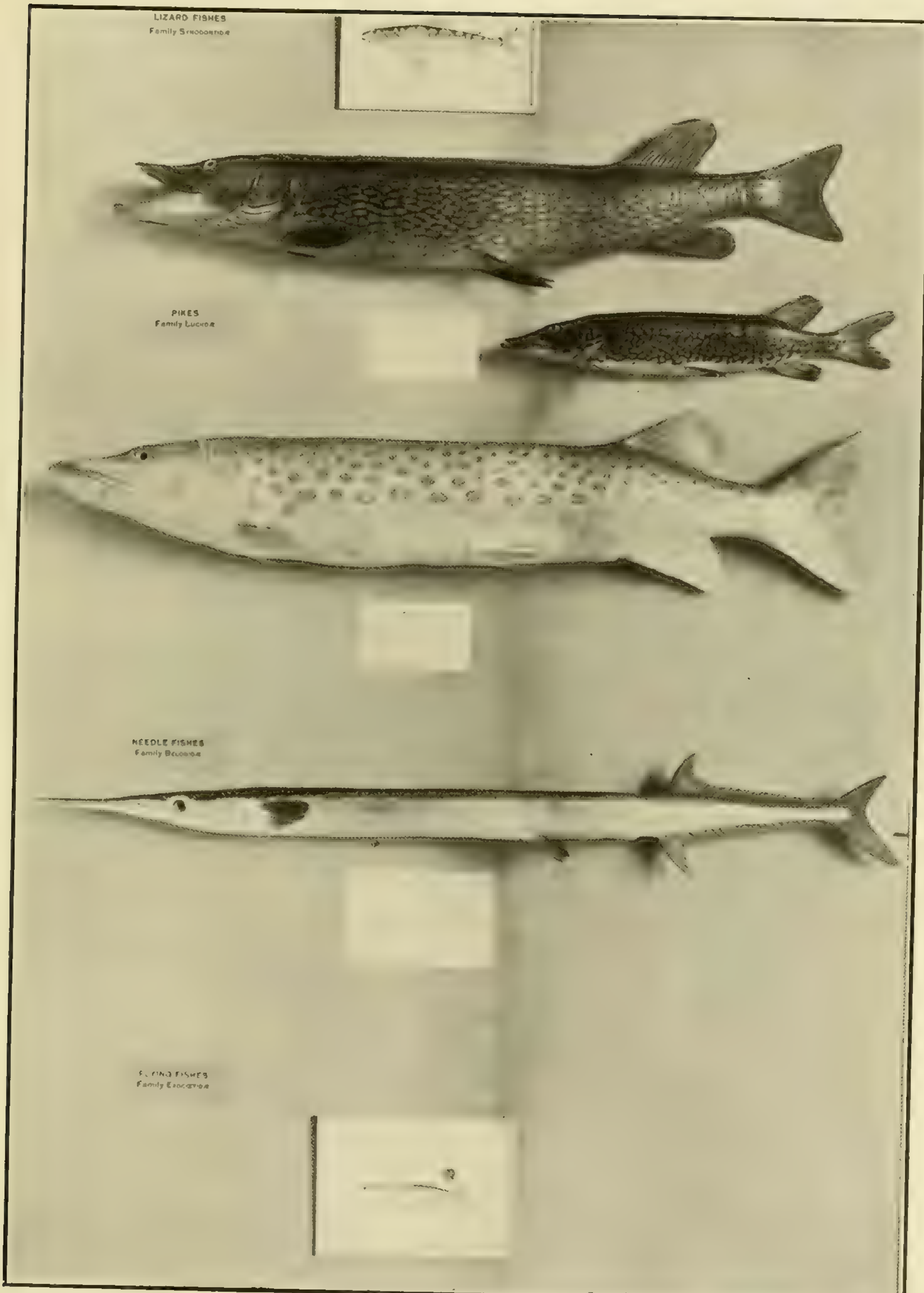
A typical case illustrating the arrangement of specimens and the method of indicating classification.

A typical case with doors open, showing character of material to be used.



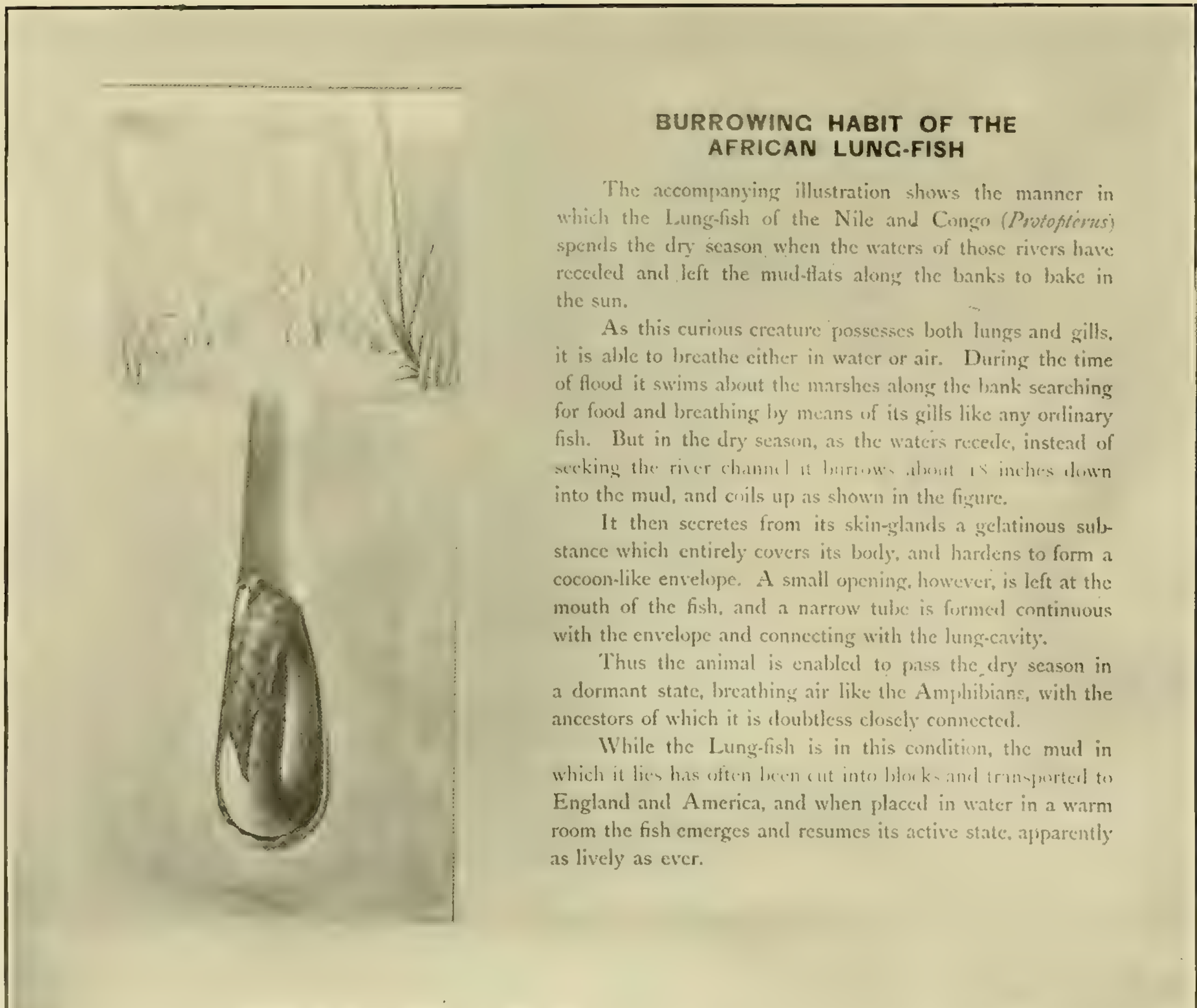
One of the shark cases.

Case devoted to the trout group. The method of indicating the suborder is well shown in this figure. The case label, hanging on the front of the case, contains a definition of the suborder.



A portion of the case devoted to the Haplomi, illustrating the use of family labels and the method of separating the families by means of strips of tape.

Method of treating large specimens to form frieze above cases.



BURROWING HABIT OF THE AFRICAN LUNG-FISH

The accompanying illustration shows the manner in which the Lung-fish of the Nile and Congo (*Protopterus*) spends the dry season when the waters of those rivers have receded and left the mud-flats along the banks to bake in the sun.

As this curious creature possesses both lungs and gills, it is able to breathe either in water or air. During the time of flood it swims about the marshes along the bank searching for food and breathing by means of its gills like any ordinary fish. But in the dry season, as the waters recede, instead of seeking the river channel it burrows about 18 inches down into the mud, and coils up as shown in the figure.

It then secretes from its skin-glands a gelatinous substance which entirely covers its body, and hardens to form a cocoon-like envelope. A small opening, however, is left at the mouth of the fish, and a narrow tube is formed continuous with the envelope and connecting with the lung-cavity.

Thus the animal is enabled to pass the dry season in a dormant state, breathing air like the Amphibians, with the ancestors of which it is doubtless closely connected.

While the Lung-fish is in this condition, the mud in which it lies has often been cut into blocks and transported to England and America, and when placed in water in a warm room the fish emerges and resumes its active state, apparently as lively as ever.

Type of label describing a life-habit, illustrated by water-color sketch.

Method of treating small fishes. The photograph is actual size.

A method of mounting a single specimen.

OUTLINE FOR AN EDUCATIONAL EXHIBIT OF FISHES

By Frederic A. Lucas

Curator in Chief, Museum of the Brooklyn Institute of Arts and Sciences

Presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908, and awarded one-half of the prize of one hundred dollars in gold offered by the Museum of the Brooklyn Institute of Arts and Sciences for the best plan for an educational exhibit of fishes

OUTLINE FOR AN EDUCATIONAL EXHIBIT OF FISHES.

By FREDERIC A. LUCAS,

Curator in Chief, Museum of the Brooklyn Institute of Arts and Sciences.

An educational exhibit of fishes is one that will convey to the average visitor an idea of the distinctive characters and anatomical structure of this zoological group and its larger divisions, and also afford information as to the appearance, special modifications, and, so far as possible, habits of typical members of these subdivisions.

First of all should be shown examples of the lancelet, lampreys, ostracophores, sharks, and one of the bony fishes, to show the various classes of vertebrates embraced in the term "fishes." This part of the exhibit should include, so far as possible, skeletons of these forms, accompanied by diagrams and explanatory labels, to make clear the characters of the various groups represented and illustrate the meaning of Acrania, Craniota, and Gnathostomata.

Then should come specimens showing the resemblances and differences between Elasmobranchii and Teleostomi, as well as the peculiarities of their skeletal, nervous, circulatory, and digestive systems. These series should preferably be displayed side by side, and should include not only actual specimens but drawings and models, especially in cases where the natural objects are so small as not to be readily seen. Here should be shown dissections of the arterial and nervous systems, and enlarged, explanatory models of more important details. For example, a dissection would show the relation of the heart to the gills and a model the structure and peculiarities of the heart.

Emphasis should be laid on the more apparent and more important characters, since as this exhibit is for the general public it should not go too much into details or attempt to display and explain characters not readily comprehended; such matters are for books and for the student.

The exhibits just described are intended to serve as a preface or introduction to the systematic series of fishes and should stand by themselves in order to be the more readily understood.

The more evident characters of the subclasses and orders are to be shown in connection with these divisions or groups in the systematic exhibit; at the same time a good-sized chart or diagram illustrating the relations of fishes to

other vertebrates and the primary divisions within the class, might well be introduced here.

The systematic series of fishes is to form the principal portion of the collection and is to include typical examples of the various subclasses and orders. It should not be too large and it should as a rule be confined to the more characteristic forms. The object of this series is to show the main divisions of fishes and give the observer an idea of their general appearance. To multiply forms and individuals would therefore be confusing and defeat the very object in view.

In selecting specimens to represent the various groups, preference should be given to the more characteristic and better-known species and, so far as possible, to species common in the vicinity[a] where the exhibit is to be displayed. The more common the species the more familiar is it to the observer, the more readily will he associate it with the fact illustrated, and the more forcibly will that fact be impressed upon him. The educational value of a specimen does not depend on its rarity but on the clearness with which it shows the fact it is intended to illustrate.

The larger extinct groups should be represented both by their fossil remains and by models or pictures, and important or readily obtainable fossil forms should be introduced in their proper places among existing species. In no way save by the use of fossils can a proper idea be given of the relationships of various groups and of their relative importance at the present time and during past geologic history.

As an adjunct to the systematic series there should be groups or pictures illustrating important or interesting points in the habits of fishes, such as the sargassum fish and stickleback with their "nests," the sunfish and its nest, the remora clinging to a shark, etc.

Small series or assemblages of fishes peculiar to certain localities or habitats could be introduced to advantage; thus a series of deep-sea forms would emphasize the peculiarities of the abyssal fauna and the remarkable modifications for life at great depths. Examples of deep-sea fishes should also be shown in their respective groups to illustrate the facts that the deep-sea fauna has been derived from that of the shallower seas and that resemblances that exist between them are largely due to adaptations toward one end—life in the depths of the sea.

One of these "supplementary series" might be devoted to the brilliant fishes of tropical waters, attention being called to the contrast they offer to the modest colored but important food fishes of temperate regions. In such "sup-

[a] For example, a museum located near the Atlantic or Pacific coast should draw for its examples, so far as possible, upon the salt water fishes, while an inland museum should select as many examples as possible from the lakes and rivers. This naturally would be practicable only to a limited extent, owing to the fact that even the most scanty representation of the principal groups of fishes calls for many species.

plementary" displays might be illustrated the difference between the sluggish bottom-frequenting species, the active pelagic forms, and the highly modified species from the abyssal regions of the sea. Here it would be necessary to call in the aid of the artist to illustrate the adaptations to environment and show how the colors of some fishes blend in with the rocks and waving sea weeds.

Among the special series, or series illustrating modification for offense and defense, for capturing food, or escaping devourers, come phosphorescent and electrical fishes. Another of these special series might well be an exhibit of game fishes, and this should be mounted as artistically as possible, with specially designed backgrounds and surroundings. Such an exhibit could be made very attractive without being in the least garish. These various series should be kept by themselves. The object of the systematic part of the exhibit is to display as plainly as possible the orders and higher groups of the class of fishes, and these distinctions should be made as clear as possible for the sake of the general visitor, for whose benefit the exhibition part of a museum is provided. The number of specimens, also, should be carefully kept down in order not to tire the visitor and confuse him with a multiplicity of forms; but there should be no hesitancy in using several specimens of the same fish if needed to illustrate more than one fact.[a] It may even be questioned if such repetition may not be advisable in order to drive home and clinch the fact that a common species is none the less a typical one and that mere rarity does not in itself mean anything.

The questions of whose classification to adopt and how it may best be illustrated are not easy to answer, because no two systematists are agreed as to the relative importance and exact position of certain groups. In the outline here presented the classification employed by Doctor Jordan in his Guide to the Study of Fishes has been followed, partly as a matter of convenience and partly on account of the amount of information contained in the book. Practical difficulties in the way of displaying any group of animals are met with in the limitations and disposition of space available for such exhibits. In many ways it seems best to indicate the divisions adopted and arrangement followed on a large label, number the orders, and repeat these numbers on the labels.

One of the physical difficulties encountered in arranging exhibits is that animals of very different sizes may be zoologically related,[b] rendering it difficult to place the specimens at once in their proper order and to permit the smaller specimens to be seen. To preserve a balance by exhibiting small examples of such species as reach a large size is to give a wrong impression to the beholder,

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[a] Burt Wilder notes this in his "Educational Museums of Vertebrates," showing how the same species may be used for several purposes.

[b] Such an instance among mammals is the relationship of rhinoceros, hyrax, and elephant.

and it is a difficult matter to correct by information on a label the effect produced by the specimens themselves. By adopting the method suggested of numbering the orders or families in accordance with a given scheme of classification the smaller animals may be placed where they may be readily seen.

If small examples of fishes that reach a large size are undesirable because they give a wrong impression to the beholder, unusually large individuals are to be ruled out for the same reason—that they give an exaggerated and incorrect idea of the species illustrated. Such specimens may, however, be shown by themselves or where they will have a decorative value, the fact that they are of exceptional size being plainly noted on the label.

It is to be constantly borne in mind that exhibits are for the public; that the average visitor is not given to studying exhibits; and that every effort should be made to have the objects shown illustrate and press home the meaning of the ideas they are intended to convey. Such being the case, the specimens chosen for display should be typical of the group or fact they are intended to illustrate. Rare or unfamiliar species should be eschewed so far as possible, for their very rarity is a drawback and militates against their teaching power.

No provision has been made in this plan for exhibiting fishery products, or methods of capturing fish, though much information in regard to such matters might be noted on the labels. There is a temptation to extend in these directions, but such exhibits should properly be kept apart, if for no other reason than the large amount of room demanded and the difficulty of telling just where to stop. Technological and commercial exhibits are capable of almost indefinite extension, and to deal with the subject of fisheries alone calls for a large museum.

No hard and fast line can be drawn as to the character of the material used for display; alcoholic specimens, casts, mounted fishes, plates, all have their uses and in some one particular each has its superiority to the others. As a rule the writer believes thoroughly good casts of fishes to be superior to other preparations for exhibition purposes, and this is particularly true of large or smooth-skinned species. For small species alcoholics, mounted in flat jars, are to be preferred, and wherever enlarged models are shown they should, if possible, be accompanied by alcoholics. The public always likes to see "the real thing" and know on what foundation a restoration or an enlargement is constructed. The preferable mode of arrangement is believed to be the alcove system with cases 9 feet high on three sides and a table or other low case in the center. An ideal method would be to have the systematic series on one side of a broad aisle, and the supplementary or special series on the other with any groups of fishes in a dark corridor close by, but the arrangement must of necessity conform to the limitations placed upon it by the plan of the building in which it is displayed.

It is believed that such an exhibit as that outlined in this paper is quite within the reach of a museum, even of moderate size. Naturally it could not be brought together all at once, but it might be assembled gradually, taking for immediate display such species as were available and waiting for the others to be acquired. Where vacancies occurred, due to the lack of species needed for the representation of important groups, this might be noted on a label, or in many instances a figure of the fish might be shown. This would call attention to the needs of the collection and might lead to securing desirable specimens.

The systematic series calls for about 175 specimens, including fossils, 44 skeletons and other anatomical pieces, and 13 figures in cases where species are rare or small; a total of 230 specimens. This may seem a small number to represent a group containing over 13,000 living species, but it would be an easy matter to add systematically to such a collection, while, on the other hand, it is believed to present a fairly good idea of the extent and principal modifications of the group.

SYNOPSIS OF ARRANGEMENT AND LIST OF PRINCIPAL SPECIMENS TO BE SHOWN.

INTRODUCTORY DISPLAY.

Fishes and fish-like vertebrates, showing the forms popularly known as fishes—the lancelet, lamprey, ostracophore, and dogfish, and the bass or other acanthopterygian. To be accompanied by skeletons and figures to make clear the meaning of such terms as Acrania, Craniota, and Gnathostomata.

THE CLASSES ELASMOBRANCHII AND TELEOSTOMI COMPARED AND CONTRASTED.

Skull of shark showing that the cranium is a mass of calcified cartilage and not composed of separate bones, and showing the manner in which the jaw is connected with the cranium. Specimen showing the separate gill openings.

Skull of bony fish, cast or specimen showing single gill opening and flap.

ANATOMY OF FISHES.

Cast showing the external topography of a fish with the name of the principal parts or regions.

Skeleton; dermal bones to be removed from one side of the skull.

Cranium of fish compared with that of mammal, the corresponding bones similarly colored. To illustrate great differences between the two groups.

Model showing the general anatomy of a teleost fish.

Dissections, accompanied by models, showing nervous and circulatory systems.

Specimens and models showing the development of a fish.

SYSTEMATIC SERIES OF FISHES.

Comprising characteristic examples of the various orders and suborders of the classes popularly known as fishes, and including specimens showing the more important or apparent characters of these groups. To consist of alcoholic and mounted fishes, casts, and anatomical specimens.

A detailed list is subjoined.

SPECIAL OR SUPPLEMENTARY EXHIBITS.

Fishes of tropical waters, showing their brilliant coloring. To be shown in a group.

Fishes of temperate seas.

Deep-sea fishes, showing their modifications for life at great depths.

Fishes of shallow waters, illustrating modifications in form and color for concealment. To be shown in one or several groups.

Electrical fishes.

Phosphorescent fishes.

Exhibit of game fishes.

Small groups, illustrating nesting habits of such fishes as *Amia*, sunfish, stickleback, chub, etc. Rarer examples may be added where obtainable.

DETAILED LIST OF FISHES FOR EXHIBIT.

Class ELASMOBRANCHII.
- Order PLEUROPTERYGII. Extinct.
  - *Cladoselache*, model.
- Order ACANTHODII. Extinct.
  - *Acanthodes*, figure.
  - *Diplacanthus*, figure.
- Order ICHTHYOTOMI. Extinct.
  - *Pleuracanthus*, figure.
  - *Pleuracanthus*, teeth and spines.
- Order NOTIDANI.
  - *Notidanus*, cast.
  - *Notidanus*, jaw or teeth.
- Order ASTEROSPONDYLI.
  - Section of vertebra showing structure.
  - *Lamna*, cast and teeth.
  - *Carcharodon*, cast and jaws or teeth.
  - *Carcharodon*, teeth of extinct *C. megalodon*.
  - *Cestracion philippi*, cast or mounted specimen; skeleton, or at least teeth.

Class ELASMOBRANCHII—Continued.
- Order TECTOSPONDYLI.
  - Section of vertebra showing structure.
  - *Squalus*.
  - *Pristiophorus*.
  - *Squatina*.
  - *Rhinobatus*.
  - *Raja*.
  - *Torpedo*.
  - *Myliobatis*.
  - *Pristis*.
  - (To be shown mainly by casts.)
  - This number of specimens is desirable to show the transition from sharks to rays.
- Order HOLOCEPHALI.
  - *Chimæra*.
  - *Chimræa*, skeleton.

Class OSTRACOPHORI.
- Order HETEROSTRACI.
  - *Lanarkia*, casts and figures.
  - *Pteraspis*.

Class OSTRACOPHORI—Continued.

Order OSTEOSTRACI.

Cephalaspis, specimens, or casts, and models.

Order ANTIARCHI.

Pterichthys, specimens, or casts, and models.

Bothriolepis.

Order ANASPIDA.

Birkenia, casts and drawings.

Order ARTHRODIRA.

Coccosteus, cast and model.

Dinichthys (if possible).

Class TELEOSTOMI, true-mouthed fishes.

Subclass CROSSOPTERYGII.

Order HAPLISTIA. Extinct.

Tarassius, figure.

Order RHIPIDISTIA. Extinct.

Holoptychius, cast.

Gyroptychius, figure.

Order ACTINISTIA. Extinct.

Undina, good figure.

Order CLADISTIA.

Polypterus, and skeleton, large figure or model of fin.

Subclass DIPNEUSTA.

Order DIPNOI.

Neoceratodus } and skeleton of one species.
Lepidosiren }

Subclass ACTINOPTERI.

Order LYSOPTERI. Extinct.

Catopterus redfieldius, specimens.

Order CHONDROSTEI, sturgeons.

Acipenser, and small skeleton.

Scaphirhynchus.

Order SELACHOSTOMI.

Polyodon, and skeleton.

Order PYCNODONTI. Extinct.

Gyrodus, cast and figure.

Order LEPISOSTEI.

Lepisosteus, vertebrae to show the procœlous type.

Lepisosteus, and skeleton.

Order HALECOMORPHI.

Amia, and skeleton.

Class TELEOSTOMI, true-mouthed fishes—Con.

Subclass TELEOSTEI, true bony fishes.

Order ISOSPONDYLI.

Salmo; Diplomystus, fossil.

Coregonus.

Alosa.

Tarpon.

Albula.

Osteoglossum.

Stomias, *Chauliodus*, deep-sea forms.

Suborder INIOMI.

Synodus, *Ipnops*, *Diaphas*, *Myctophum*—deep-sea forms.

Order APODES.

Anguilla, skeleton or at least skull.

Anguilla.

Muræna, skull.

Gymnothorax.

Leptocephalus, figures showing development of eel.

Suborder LYOMERI.

Gastrostomus, deep-sea forms.

Saccopharynx.

Order HETEROMI.

Notacanthus.

Series OSTARIOPHYSI.

Order HETEROGNATHI.

Serrasalmo, the caribe.

Order EVENTOGNATHI.

Cyprinus, and skeleton.

Notropis, or similar form.

Semotilus.

Abramis.

Good large examples of pharyngeal teeth.

Catostomus (as typically American).

Ictiobus.

Order NEMATOGNATHI.

Arius, spine of large species.

Ictalurus, and skeleton.

Ameiurus.

Malapterurus.

Schilbeodes.

Clarias.

Loricaria.

Callichthys.

Gymnotus.

Class TELEOSTOMI, true-mouthed fishes—Con.
Series OSTARIOPHYSI—Continued.
Order SCYPHOPHORI, African "elephant-fish."
Mormyrus.
Gymnarchus.
Order HAPLOMI.
Esox, and skeleton.
Umbra.
Anableps.
Fundulus.
Gambusia.
Amblyopsis.
Order XENOMI.
Dallia.
Order ACANTHOPTERYGII.
Suborder SYNENTOGNATHI.
Belone.
Exocœtus, and skeleton.
Hemirhamphus.
Suborder PERCESOCES.
Atherina
Mullus
Mugil.
Sphyræna.
Polynemus or *Polydactylus*, shoulder girdle to show structure.
Order PHTHINOBRANCHII.
Fistularia, skeleton.
Gasterosteus, shoulder girdle and enlarged drawing.
Syngnathus.
Hippocampus.
Pegasus.
Suborder SALMOPERCES.
Percopsis.
Lampris (if possible).
Semiophorus (or even cast).
Zeus faber, and skeleton.
Order BERYCOIDII.
Beryx, cranium showing orbitosphenoid.
Holocentrus.
Monocentris.
Order PERCOMORPHI.
Scomber.
Trichiurus.
Xiphias.
Carangus, and skeleton.
Coryphæna.
Gastronemus, fossil.
Suborder PERCOMORPHI.
Aphredoderus.
Roccus, skeleton.

Class TELEOSTOMI, true-mouthed fishes—Con.
Series OSTARIOPHYSI—Continued.
Order PERCOMORPHI—Continued.
Suborder PERCOMORPHI—Continued.
Eupomotis.
Micropterus.
Perca.
Stizostedion.
Etheostoma.
Asineops, fossil.
Promicrops.
Epinephelus.
Priacanthus.
Lutianus.
Hæmulon.
Upeneus.
Cynoscion.
Chiasmodon.
Lopholatilus.
Suborder LABYRINTHINCI.
Anabas scandens, if possible in climbing attitude.
Suborder HOLCONOTI.
Cymatogaster, with young
Hypsurus.
Embiotoca.
Suborder CHROMIDES.
Heros.
Priscacara, fossil.
Pomacentrus.
Suborder PHARYNCOGNATHI.
Tautoga, skull showing enlarged pharyngeals.
Ctenolabrus, cunner.
Scarus, skull with pharyngeals, or allied form.
Pseudoscarus.
Sparisoma.
Order SQUAMIPINNES.
Chætodipterus, skeleton.
Chætodon.
Holacanthus.
Acanthurus or *Teuthis.*
Order PLECTOGNATHI.
Balistes, skeleton.
Balistes.
Monacanthus.
Lactophrys.
Lactophrys, skeleton.
Lagocephalus.
Sphæroides.
Diodon.
Mola

Class TELEOSTOMI, true-mouthed fishes—Con.
- Series OSTARIOPHYSI—Continued.
  - Order PAREIOPLITAE.
    - *Sebastes* or *Sebastodes*, skeleton or skull.
    - *Sebastes.*
    - *Scorpæna.*
    - *Synanceia.*
    - *Trigla.*
    - *Cottus.*
    - *Cottus*, skeleton.
    - *Cyclopterus.*
    - *Cephalacanthus.*
  - Suborder GOBIOIDEI.
    - *Gobius*, specimen showing the ventrals joined to form a sucking disk.
    - *Periopthalmus* on tree.
    - *Typhlogobius* (if possible).
  - Suborder DISCOCEPHALI.
    - *Echeneis.*
    - *Echeneis*, skeleton showing modified fin one showing top of head.
    - *Elacate.*
  - Suborder TÆNIOSOMI.
    - *Regalecus.*
    - *Trachypterus.*
  - Order HETEROSOMATA.
    - Skeleton of good-sized specimen.
    - *Platophrys.*
    - *Lophopsetta.*
    - *Hippoglossus.*

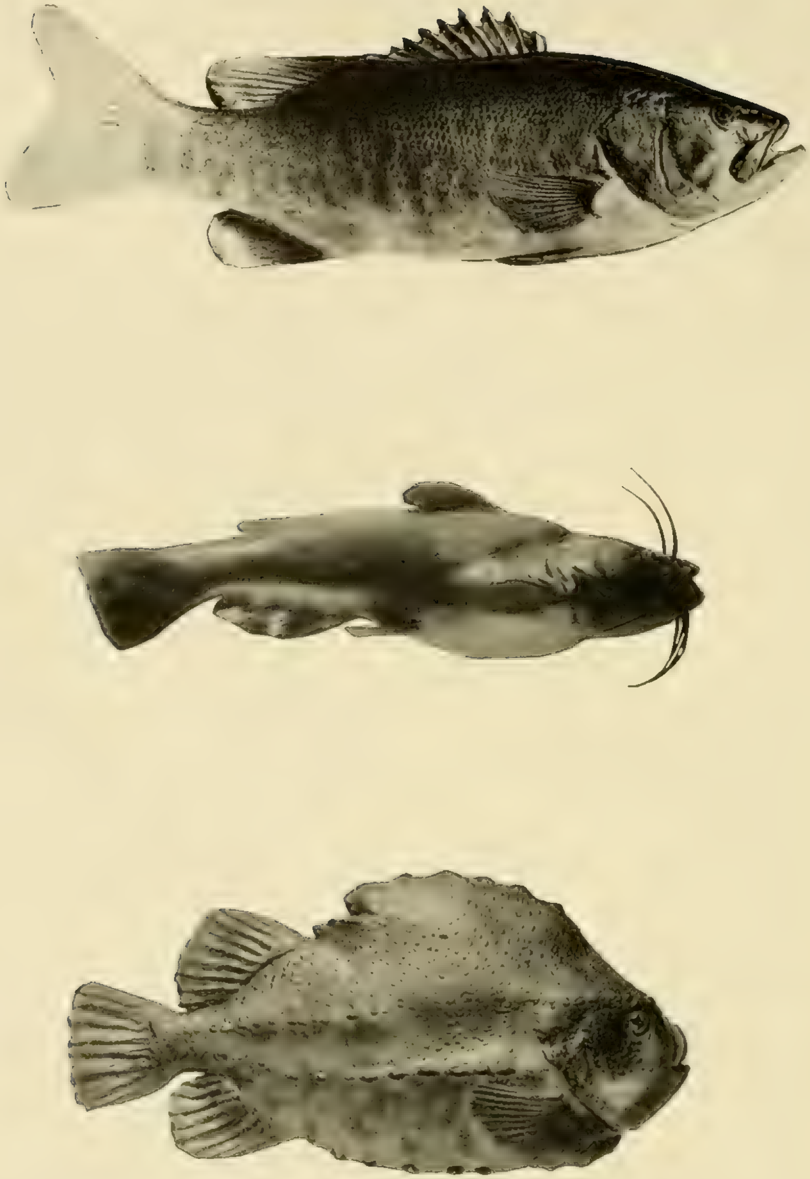
Class TELEOSTOMI, true-mouthed fishes—Con.
- Series OSTARIOPHYSI—Continued.
  - Order HETEROSOMATA—Continued.
    - *Paralichthys.*
    - *Solea.*
    - *Symphurus.*
  - Suborder JUGULARES.
    - *Uranoscopus* or *Astroscopus.*
    - *Blennius.*
    - *Anarichas*, skull.
    - *Anarichas.*
    - *Zoarces.*
    - *Brotula.*
    - *Opsanus tau.*
  - Order OPISTHOMI.
  - Order ANACANTHINI.
    - *Gadus.*
    - *Gadus*, skeleton.
    - *Lota* (as a fresh-water form).
    - *Cœlorhynchus*, grenadier.
    - *Albatrossia* or *Steindachnerella*, deep-sea form.
  - Order PEDICULATI.
    - *Lophius.*
    - *Lophius*, skeleton.
    - *Cryptosaras*, deep sea.
    - *Ceratias*, deep sea.
    - *Antennarius.*
    - *Ogcocephalus*, *Malthe.*

A METHOD OF PREPARING FISHES FOR MUSEUM AND EXHIBITION PURPOSES

By Dwight Franklin

American Museum of Natural History, New York City

Models presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908 and awarded the prize of one hundred dollars in gold offered by the American Museum of Natural History for the best method of preparing fishes for museum and exhibition purposes



Reproductions from photographs of models of black bass, catfish, and lumpfish. Models prepared by Dwight Franklin.

A METHOD OF PREPARING FISHES FOR MUSEUM AND EXHIBITION PURPOSES.

By DWIGHT FRANKLIN,
American Museum of Natural History, New York City.

The preparation of fish for museum and exhibition purposes has always presented considerable difficulty. In most museums three methods of representation are in vogue, namely, by alcoholics, mounted skins, and plaster casts. The following are some of the commonly accepted objections to these methods: (1) Specimens preserved in any known liquid lose their color and give little idea of the living fish. (2) Few fish can be successfully mounted, as the soft parts about the head and fins shrivel and the skin becomes dry and opaque, so that no amount of skillful coloring can restore the original translucency. If the specimen is coated with wax the detail is lost, while the softness is only on the surface of the fish, not a part of it. (3) Plaster casts may reproduce the form perfectly, but all translucency is lost. If in the last method, however, a medium could be used which is itself soft and semitransparent, the result would prove more satisfactory. It has been found that wax answers this purpose admirably. It is easily handled, retains its form, and may be successfully colored.

The method used in making the specimens shown in the accompanying illustrations is as follows:

First remove the slime from the fish and pose the animal as desired. If a cast of one side only is desired the specimen may be backed up with clay.

Now pour plaster over the fish and allow it to harden thoroughly, after which the fish may be removed from the mold and laid aside.

As a third step soak the mold in hot water until it is saturated, then absorb the excess water from the surface.

Finally pour melted beeswax of the desired color into and out of the mold until a thick coating of wax is formed, then allow it to cool. Before the wax has hardened wire hangers may be inserted.

When the cast is cold carefully chip off the plaster mold, point up the wax cast, if necessary, and there has been produced a lifelike reproduction of the fish, which needs only to be finished by being colored accurately.

Models prepared by this method are shown in plate CXLII.

NEW METHODS OF PREPARING FISHES FOR MUSEUM EXHIBIT

By J. D. Figgins

American Museum of Natural History, New York City

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

NEW METHODS OF PREPARING FISHES FOR MUSEUM EXHIBIT.

By J. D. FIGGINS,
American Museum of Natural History, New York City.

The three essential characters in a fish specimen perfectly prepared for museum exhibition are accuracy of form and detail, durability, and lifelike coloring. As none of these features are assured by the old methods of casting and mounting this class of specimens, the result has never proved entirely satisfactory to those desiring a high class of work. Indeed, much experimenting and a study of the various methods of mounting fishes convinced me that perfect work was impossible; serious shrinkage is inevitable and a mounted fishskin represents nothing more than an inferior surface for painting. Plaster casts from molds of the same material have the advantage of more accuracy of form, but the preparation of the mold for casting and the defective plastic quality of even very thin plaster is accentuated in the cast, with the result of a lamentable lack of fine definition of detail. Besides, being extremely fragile, such casts are a constant source of annoyance, and when even slightly broken their value is seriously impaired, if not totally destroyed.

One of the most difficult problems has been the painting of such specimens. In a mounted fish the use of white lead is necessary to overcome the discoloration due to the chemical action of preservatives; and, while the lead may be eliminated in casts, the result is invariably flat and lacks the depth and brilliancy of colors so essential to a representation of life. Coloring, however, must of necessity remain in the hands of the artist to whom the work is assigned, and I will but outline the several advantages the here-described methods present for overcoming the chief difficulties.

Briefly, this is the opportunity to discard the use of lead entirely; there is necessity for using only the slightest stain to obtain the desired colors, thus securing their full transparency and brilliancy while at the same time preserving the minute detail which is invariably lost by the use of lead or heavy color.

In experimenting for an improvement in fishes for exhibition, the cost of production has been kept in mind, and at the same time an opportunity for

more advantageous field work. Those familiar with the difficulties of securing fresh specimens will appreciate the benefits to be derived through the possibility of preparing specimens in the field, and, though some of the materials are more expensive than those used in the old methods, the saving of time and labor more than compensates for the difference.

These methods are equally applicable in the preparation of reptiles and batrachians. Specimens so treated readily admit of close inspection with the magnifying glass; therefore, their value is enhanced through the opportunity presented for scientific study.

While I do not recommend plaster casts, except for some of the large fishes and reptiles, the obvious superiority of glue molds over those of any other material, when such casts are desired, should be so apparent that mention of their several distinct advantages is hardly necessary.

I. WAX CASTS FROM GLUE MOLDS.

The peculiar plasticity and toughness of glue makes it a singularly desirable material for molds if either plaster or wax casts are desired, as it takes an exact impression of the most intricate detail or undercut, and when withdrawn retains its perfect negative form. Being softer than wax, when the slight shrinkage of the latter takes place the glue prevents the cracking and damage to definition so noticeable when hard molds are employed. The process in detail is as follows:

White glue is first softened by soaking in water; then the latter is drained off and the glue melted slowly and thickened somewhat by cooking in a double boiler or water bath. When sufficiently cool almost to permit immersing the hand without discomfort, the glue is in proper condition for flowing. Pose the fish by laying flat on some solid base, and build potters' clay about the side until the desired position is obtained. The clay immediately beneath the fins and tail should be smooth and at a height sufficient to permit the latter to be distended upon it, where, if necessary, they may be made secure by the use of insect pins. After applying over the entire surface of the fish a very thin coat of stearin dissolved in kerosene, carefully wipe with a soft cloth to remove any excess of oil.

A clay dam is now constructed about the specimen to the height of an inch or two above the highest point of the latter, and an equal distance from its outer edge; then the glue may be flowed. The glue should be poured directly upon the specimen, but very slowly, otherwise air spaces may occur. This is allowed to stand for a few hours, or until thoroughly chilled, when the clay dam may be removed and an inch of plaster spread over the entire surface of the mold. This acts as a "case" and holds the mold in its proper form during the later stages of the work.

Take the mold from the case, and, by slight manipulation, the specimen is removed without damage to either. Thoroughly work talcum powder into the mold, with a soft brush, to remove the oily surface, and immerse in a 5 per cent solution of formalin (measuring the latter as if 100 per cent) for five minutes. The surface of the glue is thus hardened, and only requires a few minutes in water, heated to a temperature of about 100° F., to prevent a too sudden chilling of the wax. Remove the excess of water with a soft sponge, and, after quickly applying a very thin coat of oil, the mold is ready for filling.

The transparency of the specimen must govern the composition of the wax for casting, but the following formula will prove generally useful. Melt in the double boiler one pound of paraffin to four pounds of bleached beeswax, to which add one teaspoonful of Canada balsam, or Venetian turpentine, to each pound of wax. Color with oil, tube colors, to the lightest tint of the ground color of the specimen.

As the fins and tails of fishes need strengthening, fill the mold and, after allowing it to stand a minute or two, empty it of all the wax except the thin film which will have formed over the surface, and while still hot press a single thickness of bolting cloth along the fins and tail; also add a silk covered wire at the spines, dashing a small quantity of wax over all to keep in position, when the mold should be again filled. The entire cast may be given additional strength by applying one or two coats of the cloth over the entire surface.

The principal care to be exercised in this work is in the flowing of the wax. There should be no splashing and the stream should be steady and constant, otherwise "water marks" and other possible defects will result.

Haste to remove the cast from the mold should be avoided, and under no circumstances should artificial means for cooling be employed, but the mold should be allowed to stand undisturbed until the wax is cold.

In pouring the wax into molds that present deep depressions or offsets, it is often necessary to resort to tilting or rolling the mold to insure the proper filling, and this should be done as the wax is deposited. It is advisable after such a mold is full to pour out a part of the wax and turn the mold at various angles to remove possible air bubbles, after which it is refilled.

In most instances the mold is easily taken from about the cast; but when deep undercuts are present the glue can be removed by cutting away in small sections or, more often, by merely splitting down the center. This is recommended where there are delicate parts which need care. A saving of material may be accomplished by inserting a rough form of wood and filling the intervening space with melted wax.

With fishes presenting a strong contrast of color, excellent results are obtained by tinting wax the several colors represented and applying each in its relative position with a soft brush. To do this properly, the mold must

first be immersed in water slightly warmer than the temperature mentioned. In no circumstances attempt to brush the wax on, but fill the brush and dab it on with one stroke of the end of the bristles, repeating until the surface is well coated, when the cloth and wire may be added as above described.

II. PLASTER CASTS FROM GLUE MOLDS.

When plaster casts are desired, the mold is prepared and treated as in wax casting, except that the warm-water bath may be omitted. With a soft brush work the thinly mixed plaster into every part of the mold until a coat has been applied to the entire surface.

While this coating is in a semisoft condition, dip white mosquito netting into thin plaster and lay on one or two thicknesses to increase the strength of the cast. The addition of burlap treated in the same manner will greatly assist in reducing the weight of such specimens. During warm weather it is advisable to inject and wash the specimen with formalin before posing, to prevent the quick decomposition likely to follow the application of the warm glue. As a further precaution the cooling process may be hastened by artificial means.

III. FISHES IN COPPER, FROM WAX MOLDS BY ELECTROPLATING PROCESS.

The most difficult part of the work of preparing fishes is the reproduction of their silver and iridescent colors. Metal "leaf" and washes produce but a slight resemblance to the original, and the resultant loss of detail and final discoloration of parts so treated emphasizes the necessity of preparing the highly metallic colored specimens in a manner whereby these difficulties may be avoided.

Some of the iridescent tints are imitated by the use of prismatic colors, but a white silver, or the various shades of this metal, as seen in the color of fishes, are possible only through a solid silver base.

Leaf and metal washes are not only dull in color, but are greatly darkened through the refraction of light, and it is impossible to secure brilliant effects by their use. The below-described method overcomes these difficulties, and such specimens are not only accurate of form and detail, but are durable.

The fish is posed as for glue molds, except the clay dam and coating of oil, which are omitted. The proportion of two pounds of paraffin to two pounds of bleached beeswax is melted in the double boiler and one tablespoonful of Canada balsam added to that quantity. Best results in flowing the wax are obtained by beginning at the tail with sufficient wax in a dipper (or other easily handled vessel) to insure a speedy and complete covering of the entire specimen. Allow the excess of wax to flow off and repeat several times at intervals, when a layer of absorbent cotton is spread on and saturated with the wax. In this

way a half-inch mold is built up. When it is cold, cut away all the wax about one inch outside the line of fins and tail, and apply a thin plaster case.

The fish is removed by gentle manipulation or possibly dissection, after which the mold is thoroughly cleansed by the use of a very soft brush and cold water and allowed to dry.

As pamphlets giving a complete description of copperplating are easily obtained, repetition on this subject is unnecessary here. The work does not require the services of an expert, and anyone of ordinary mechanical skill can arrange the apparatus and follow the simple directions.

When a substantial layer of copper has been deposited, the case is broken away and the wax mold removed by immersing in boiling water. After cutting and grinding away the excess of copper about the edges of the model by the use of an emery wheel or coarse file, bring the fins and tail down to a thin edge by the same method, and finish the outline with very fine files.

The model is then given a very thin plating of pure silver. This plating gives not only the full whiteness of the metal but permits of a variety of delicate shading and obviates the necessity for the use of white lead in coloring.

At first glance this method may appear too expensive for practical purposes, but with the electroplating performed by the preparator, it will prove of less cost than some of the methods now in use.

THE UNITED STATES BUREAU OF FISHERIES

ITS ESTABLISHMENT, FUNCTIONS, ORGANIZATION RESOURCES, OPERATIONS, AND ACHIEVEMENTS

By Hugh M. Smith

Deputy Commissioner of Fisheries

Paper presented before the Fourth International Fishery Congress held at Washington, U. S. A., September 22 to 26, 1908

CONTENTS.

	Page.
Establishment and functions	1367
Organization	1369
Resources and investment	1370
Cultivation and distribution of food fishes	1371
General importance and extent	1371
Species cultivated	1372
Hatcheries operated	1373
Output and its distribution	1379
Popularity of the work	1382
Scientific inquiry	1383
Statistics and methods of the fisheries	1385
Alaska salmon-inspection service	1392
Relations with the States and with foreign countries	1393
Publications	1395
Some results of the work	1398
Fish culture	1398
Acclimatization	1402
Biological investigations and experiments	1406
Commercial fisheries	1410

UNITED STATES COMMISSIONERS OF FISHERIES.

G. BROWN GOODE,
1887–1888.

MARSHALL MCDONALD,
1888–1895.

SPENCER F. BAIRD,
1871–1887.

JOHN J. BRICE,
1896–1898.

GEORGE M. BOWERS,
1898 to date.

THE UNITED STATES BUREAU OF FISHERIES:

ITS ESTABLISHMENT, FUNCTIONS, ORGANIZATION RESOURCES, OPERATIONS, AND ACHIEVEMENTS.

By HUGH M. SMITH,
Deputy Commissioner of Fisheries.

ESTABLISHMENT AND FUNCTIONS.

Prior to 1871 there was no branch of the United States Government especially charged with the consideration of fishery affairs, although fishery questions of greater or less import, some domestic, some foreign, had been arising ever since the achievement of national independence. Several of the States had already established fish commissions, and there arose among the state fishery authorities and the members of the American Fish Cultural Association (now the American Fisheries Society) an urgent demand for a national bureau devoted to fishery interests. Congress was thus influenced to action, and in the year named passed a joint resolution creating the office of Commissioner of Fish and Fisheries, whose duties were specified as follows:

> The Commissioner of Fish and Fisheries shall prosecute investigations and inquiries on the subject, with the view of ascertaining whether any and what diminution in the number of the food-fishes of the coast and the lakes of the United States has taken place; and, if so, to what causes the same is due; and also whether any and what protective, prohibitory, or precautionary measures should be adopted in the premises; and shall report upon the same to Congress.

It was further provided that the commissioner should be a civil officer of the Government, of proved scientific and practical acquaintance with the fishes of the coast, who would serve without additional compensation. The man generally regarded as preeminently qualified for the new position was Spencer Fullerton Baird, then Assistant Secretary of the Smithsonian Institution, who

received the appointment, at once entered on his duties, and continued the efficient and highly respected head of the commission until his death, in 1887.

Professor Baird was succeeded by one of his ablest assistants, Dr. George Brown Goode, eminent as administrator, ichthyologist, and fishery expert, who, however, voluntarily relinquished the commissionership after less than a year's incumbency in order to devote his entire time to the National Museum, of which he was director. Next came Commissioner McDonald, practical fish culturist and inventor of important mechanical appliances now used in the hatching of fish all over the world, who served until his death, in 1895, and was the first salaried commissioner. He was followed by Capt. John J. Brice, a retired naval officer, who held the office for two years and was succeeded in 1898 by the present commissioner, Hon. George Meade Bowers, under whose ten years' administration the service has grown in all its branches.

From the very outset of its career, the fishery service has had the active support and cooperation of many of the leading biologists, fish culturists, and fishery experts of the country, whose volunteer assistance has been an important factor in its development and efficiency. The early years of the Bureau were devoted to an active investigation of the condition of the fisheries of the Atlantic coast, Great Lakes, and other sections; to studies of the interior and coastal waters and their inhabitants, and to exploration of the offshore fishing banks. The cultivation of useful fishes was soon taken up throughout the country, and quickly attained large proportions. The natural expansion of the work was materially augmented from time to time by acts of Congress, and in a comparatively short time the operations came to have a very wide scope. In more recent years the work has been still further extended, so that at present there is scarcely a phase of aquiculture, of the fishing industry, or of biological and physical science as connected with the waters that does not come within the purview of the Bureau.

For many years the Bureau was without any executive control in fishery affairs. Under the Constitution the States legislate for themselves in such matters and the Federal Government has assumed no jurisdiction. The Bureau thus had no direct voice in the making or enforcing of any measures for the protection or preservation of aquatic animals, and its position, compared with the fishery service of other countries, was anomalous. In its advisory capacity, however, the Bureau has acquired an influence upon fishery legislation, and has now been given executive powers in Alaska for the enforcement of a comprehensive code of laws affecting the salmon fisheries. In the interests of the fur-seal fisheries the Bureau has since 1893 been called on to study the life history and migrations of the seals, to inspect conditions on the islands, and to submit recommendations concerning the killing of the animals.

ORGANIZATION.

Until 1903 the Bureau was known as the "United States Commission of Fish and Fisheries," and was an independent institution of the Government, responsible directly to Congress. In that year it was included in the new Department of Commerce and Labor, becoming the United States Bureau of Fisheries, as known at present.

The work at the outset naturally fell under the three general heads of scientific investigation, fishery inquiry, and fish culture. This classification has been extended and perfected, and enters into the organization at the present time.

The permanent personnel of the service includes 325 persons, of whom 83 are on duty in Washington and 242 are at outside stations, at laboratories, and on vessels. The officials under the commissioner are a deputy commissioner, a chief clerk, and a chief of each of the three divisions before referred to. All subordinates are appointed, after passing the prescribed examinations, from the registers maintained by the Civil Service Commission.

The deputy commissioner is the executive next to the commissioner, and acts with full powers in the latter's absence. The commissioner's office, which represents the administrative division of the Bureau and has the chief clerk at its head, has under it the accounting office, the office of the architect and engineer, and the office of vessels, in addition to the library, records, correspondence, and property. In this division there is a technical and clerical force of 20 persons, not including messengers, watchmen, janitors, engineers, firemen, and laborers, and the 34 civil employees in the vessel service.

The chief of the Division of Fish Culture, with an office force of 7, directs the operations at the hatcheries and the planting of fish. Each hatchery has a force consisting of a superintendent, fish culturist, skilled laborers, etc., the number of employees for all the stations reaching a total of 168. In addition to these there are 13 superintendents, fish culturists, and other employees at large. During the busy seasons the hatchery force is increased by the temporary employment of many spawntakers and laborers as the work requires. For the distribution of eggs and young fish there are 6 transportation cars permanently provided with crews of messengers, numbering in all 26 men. The car and messenger service is under the immediate direction of a superintendent.

The Division of Scientific Inquiry includes besides its chief 6 scientific assistants and a number of clerks. Three special agents are employed in the Alaska inspection service, which is under this division, and 3 persons are permanently employed at the biological laboratory at Beaufort, N. C. Numerous investigators and assistants are also employed temporarily as needed for the study of special problems at the laboratories and in the field.

In the Division of Statistics and Methods of the Fisheries there are the chief, 4 statistical field agents, 2 local agents, and 8 clerks, some of whom are available for field work.

RESOURCES AND INVESTMENT.

The only funds available for the operation of the Bureau are the moneys voted annually by Congress. The comparatively large sums collected yearly in the Alaska salmon-inspection service are covered intact into the Treasury. From its very modest beginning, with $5,000 allowed for its work, the Bureau has won such recognition from Congress that the appropriations for its maintenance have increased steadily, and for the current fiscal year, ending June 30, 1909, reached the substantial amount of $803,920, apportioned as follows:

Administration:	
Salaries	$45,380
Miscellaneous expenses	8,000
Propagation of food fishes:	
Salaries—	
Office	11,820
Stations and field service	156,420
Car and messenger service	23,100
Miscellaneous expenses	275,000
Inquiry respecting food fishes:	
Salaries—	
Office	13,640
Biological station at Beaufort, N. C	2,700
Miscellaneous expenses	30,000
Statistical inquiry:	
Salaries	17,140
Miscellaneous expenses	7,500
Vessel service:	
Salaries	29,420
Miscellaneous expenses	70,000
Alaska salmon-inspection service (salaries)	6,300
Special:	
Establishment of station for propagation of fresh-water mussels in Mississippi Valley	25,000
Construction of new steam vessel for Alaska service	20,000
Improvements and repairs at stations	44,500
Repairs to steamer Albatross	18,000
Total	803,920

The land owned and occupied by the Bureau at its fish-cultural and biological stations has an aggregate area of over 12,000 acres, with a value of $240,000. The improvements and equipments at these stations represent an investment of more than $1,000,000. Other property of the Bureau includes 4 seagoing steam and sail vessels, 20 steam launches, and 150 small sail, power, and row boats, which, with equipment, have a value of $300,000. Its 6 fish-transportation cars are valued at $45,000. The aggregate investment of the Federal Government in property devoted to the fishery service is thus about $1,585,000.

Headquarters of the Bureau of Fisheries, Washington, D. C.

Superintendent's residence at a New England trout-hatching station.

CULTIVATION AND DISTRIBUTION OF FOOD FISHES.

GENERAL IMPORTANCE AND EXTENT.

The artificial propagation of fishes was not contemplated at the time the Bureau was formed, but was instituted by an act of Congress in 1872 at the instigation of the American Fish Cultural Association, which had been organized two years before and had taken a leading part in the establishment of the Bureau. The fishes to which attention was given first were the shad, the Atlantic salmon, and the whitefish. This work proved so popular that it was extended annually, was supplemented by efforts in acclimatization, and soon overshadowed all other branches.

The Bureau has labored to make its operations commensurate with the extent of the fisheries in public waters, and with the inevitable exhaustion of the native fish life in the smaller lakes and streams incident to the development of the country and the increase of population. The policy, as enunciated by Doctor Goode, has been to carry out the idea that it is better to expend a small amount of public money in making fish so abundant that they can be caught without restriction and serve as cheap food for the people at large than to expend a much larger sum in preventing the people from catching the few fish that still remain after generations of improvidence.

From this standpoint it is perhaps fortunate that up to the present the Bureau has not had to devote its major energies to the formulation and enforcement of fishery legislation, but has been able to work directly for the increase of fish life. Public or government fish culture has in America attained tremendous proportions, and exceeds in extent and importance that of all other countries combined. However, the neglect of some of the States to provide the minimum protection to certain species inhabiting interstate and international waters has not only negatived the fish-cultural work of the Bureau and of the States themselves, but has practically inhibited it by preventing the possibility of securing an adequate supply of eggs, thus making desirable and necessary the institution of a new policy placing interstate and international waters under the jurisdiction of the General Government.

In the work of the Bureau of Fisheries the United States Government has an especial and unique claim to the epithet "paternal." The stocking of waters with food fishes is a direct benefit to the public, not only increasing the very material that supports an enormous industry, but providing food itself for the individual who will use his hook and line. From year to year, as the importance of the work has become increasingly evident, additional hatcheries have been built, the capacity of existing hatcheries has been enlarged, the scale of the operations has been extended, new kinds of fishes have been added to the output, and new sections have been brought under the direct influence of the work.

THE SPECIES CULTIVATED.

At the end of the first ten years of the Bureau's existence the fishes that were being regularly cultivated were shad, carp, chinook salmon, Atlantic salmon, landlocked salmon, rainbow trout, brook trout, and whitefish, in addition to which the propagation of several others had been undertaken experimentally. The list now is six times as long, and the annual output is ten times the aggregate for the ten-year period ended in 1881. The main energies are devoted to the important commercial fishes—shad, whitefish, lake trout, Pacific salmons, white perch, yellow perch, cod, flatfish—and the lobster, which are hatched in lots of many millions annually. More widely popular, however, are the distributions of the fishes of the interior waters which are generally classed as game fishes. Although representing only about 10 per cent of the output of the hatcheries, this feature of the work is very important, for it supplies choice kinds of fish for public rivers, lakes, and ponds, and for fishing preserves and private ponds and streams in all parts of the United States. The fishes most in demand for these purposes are the landlocked salmon, the different species of trout, the grayling, the basses, the crappies, the sunfishes, and the catfishes, but various others also are handled. Following is a classified list of the native fishes artificially propagated during 1908:

THE CATFISHES (SILURIDÆ):
- Spotted cat, blue cat, channel cat (*Ictalurus punctatus*).
- Horned pout, bullhead, yellow cat (*Ameiurus nebulosus*).
- Marbled cat (*Ameiurus nebulosus marmoratus*).

THE SHADS AND HERRINGS (CLUPEIDÆ):
- Shad (*Alosa sapidissima*).

THE SALMONS, TROUTS, WHITEFISHES, ETC. (SALMONIDÆ):
- Common whitefish (*Coregonus clupeiformis*).
- Lake herring, cisco (*Argyrosomus artedi*).
- Chinook salmon, king salmon, quinnat salmon (*Oncorhynchus tschawytscha*).
- Silver salmon, coho (*Oncorhynchus kisutch*).
- Blueback salmon, redfish, sockeye (*Oncorhynchus nerka*).
- Humpback salmon (*Oncorhynchus gorbuscha*).
- Steelhead (*Salmo gairdneri*).
- Rainbow trout (*Salmo irideus*).
- Atlantic salmon (*Salmo salar*).
- Landlocked salmon (*Salmo sebago*).
- Yellowstone Lake trout, cut-throat trout, black-spotted trout (*Salmo lewisi*).
- Colorado River trout, black-spotted trout (*Salmo pleuriticus*).
- Golden trout (*Salmo roosevelti*).
- Lake trout, Mackinaw trout, longe, togue (*Cristivomer namaycush*).
- Brook trout, speckled trout (*Salvelinus fontinalis*).
- Sunapee trout (*Salvelinus aureolus*).
- Canadian red trout (*Salvelinus marstoni*).
- Hybrid trout (*Salvelinus aureolus + fontinalis*).

THE GRAYLINGS (THYMALLIDÆ):
- Montana grayling (*Thymallus montanus*).

THE BASSES, SUNFISHES, AND CRAPPIES (CENTRARCHIDÆ):
- Crappy (*Pomoxis annularis*).
- Strawberry bass, calico bass (*Pomoxis sparoides*).
- Rock bass, red-eye, goggle-eye (*Ambloplites rupestris*).
- Warmouth, goggle-eye (*Chænobryttus gulosus*).
- Small-mouth black bass (*Micropterus dolomieu*).
- Large-mouth black bass (*Micropterus salmoides*).
- Bluegill sunfish (*Lepomis pallidus*).

THE PERCHES (PERCIDÆ):
- Pike perch, wall-eyed pike, yellow pike, blue pike (*Stizostedion vitreum*).
- Yellow perch (*Perca flavescens*).

THE SEA BASSES (SERRANIDÆ):
- Striped bass, rockfish (*Roccus lineatus*).
- White bass (*Roccus chrysops*).
- White perch (*Morone americana*).
- Yellow bass (*Morone interrupta*).

THE DRUMS (SCIÆNIDÆ):
- Fresh-water drum (*Aplodinotus grunniens*).

THE LABRIDS (LABRIDÆ):
- Tautog, blackfish (*Tautoga onitis*).

THE CODS (GADIDÆ):
- Cod (*Gadus callarias*).
- Pollock (*Pollachius virens*).
- Haddock (*Melanogrammus æglifinus*).

THE FLOUNDERS (PLEURONECTIDÆ):
- Winter flounder, American flatfish (*Pseudopleuronectes americanus*).

CRUSTACEANS:
- American lobster (*Homarus americanus*).

In addition to the foregoing, various kinds of fishes are obtained from the overflows in the Mississippi Valley and distributed. Among these are the small-mouth buffalo-fish (*Ictiobus bubalus*), the pike (*Esox lucius*), the pickerel (*Esox reticulatus*), and several sunfishes (chiefly *Eupomotis gibbosus*). From this same source are also collected large numbers of large-mouth black bass, crappies, rock bass, and bluegill sunfish. The following introduced species are cultivated to a limited extent:

Carp (*Cyprinus carpio*). Propagated chiefly for food for other fishes.
Goldfish (*Carassius auratus*). Propagated for ornamental purposes.
Tench (*Tinca tinca*). Cultivated varieties, green tench and golden tench; propagated for ornamental purposes.
Ide (*Leuciscus idus*). Cultivated variety, golden ide; propagated for ornamental purposes.
European sea trout (*Salmo trutta*).
Loch Leven trout (*Salmo trutta levenensis*).

THE HATCHERIES OPERATED.

Fish-cultural stations are established by special act of Congress, and their location and construction are determined by the Bureau after a careful survey of the available sites in a given State. The plans and specifications for each station are prepared in the office of the architect and engineer with reference to

the nature of the operations to be conducted and the topographical conditions, and the work of constructing buildings and ponds is usually done by contract. Sometimes, however, the Bureau takes direct charge of construction, as in the case of the salmon hatcheries in Alaska.

The usual buildings at a fish-cultural station are the hatchery proper, a residence for the superintendent and his family, and necessary outbuildings. At some stations there may be also power house, foreman's or fish-culturist's dwelling, mess hall, and stable. The superintendent's and other quarters are furnished gratis, but station employees provide their own subsistence.

All sections of the country are now familiar with government fish-cultural work. In addition to the regular hatcheries, with their permanent personnel and living quarters, there are maintained numerous auxiliary hatcheries or substations which from the nature of their work do not require a permanent force and are therefore, for economic and administrative considerations, operated as adjuncts of near-by hatcheries. Some of the auxiliary stations, however, have more extensive operations than the hatcheries with which they are connected, and such will doubtless in time be made regular stations. There is also another class of stations, known as field or collecting stations, which serve as temporary headquarters for parties engaged in obtaining eggs from wild fishes. In 1908 the fish-cultural work was conducted in 27 States and Territories at 55 hatcheries and subhatcheries and 64 field stations.

While marine operations have been conducted from time to time at various places on the Atlantic coast from Maine to Florida, and have been addressed to a large number of species, the only permanent marine hatcheries are in Maine and Massachusetts, with the species handled at each as indicated in the following table. The places shown under each station are the centers of egg-collecting operations. Other sea fishes that have in previous years been artificially propagated and may again come under the hand of the fish-culturist are the haddock, the scuppaug, the sheepshead, the sea bass, the mackerel, and the squeteague, some of which were hatched on the steamer *Fish Hawk* in Chesapeake Bay and Florida.

Marine hatchery and laboratory, Woods Hole, Mass., established twenty-five years ago, and devoted to the culture of cod, flounders, and lobsters, the output of which in 1908 was 337 millions. Also the headquarters of important biological investigations of the east-coast fauna, the laboratory privileges being accorded gratuitously to qualified students.

Residence at the marine station, Woods Hole, Mass., formerly the summer headquarters of the Bureau, and now occupied by the officials of the laboratory and hatchery and by temporary assistants engaged in special work. (See p. 1384.)

MARINE HATCHERIES.

Location.	Species handled.
Boothbay Harbor, Me	Cod, lobster.
Pemaquid, Me	Lobster.
Portland, Me	Lobster.
Kittery Point, Me	Lobster.
Gloucester, Mass	Cod, pollock, flatfish, lobster.
Beverly, Mass	Lobster.
Boston, Mass	Lobster.
Cohasset, Mass	Lobster.
Hull, Mass	Lobster.
Marblehead, Mass	Lobster.
Plymouth, Mass	Cod.
Portsmouth, N. H	Lobster.
Rockport, Mass	Lobster.
Woods Hole, Mass	Cod, tautog, flatfish, lobster.
Chilmark, Mass	Lobster.
Dartmouth, Mass	Lobster.
East Greenwich, R. I	Flatfish.
Gay Head, Mass	Lobster.
Gosnold, Mass	Lobster.
Nantucket, Mass	Lobster.
Plymouth, Mass	Cod.
Sandwich, Mass	Lobster.
Waquoit, Mass	Flatfish.
Westport, Mass	Lobster.
West Tisbury, Mass	Lobster.
Yarmouth, Mass	Lobster.

The fish-cultural work on the eastern coast streams was centered at 6 hatcheries and subhatcheries in 1908. At 1 of these the principal species handled is the Atlantic salmon, at 4 the shad, at 3 the yellow perch, at 2 the white perch, and at 1 the striped bass. In recent years the Bureau has operated a shad hatchery on the Delaware River, and has detailed the steamer *Fish Hawk* for shad hatching in Maine, New Jersey, North Carolina, and Florida. The central station, in Washington, is operated largely for experimental and exhibition purposes, but sometimes receives large numbers of eggs from the adjacent river stations, especially when the latter are overstocked.

HATCHERIES ON EAST COAST RIVERS.

Location.	Fishes handled.
Craig Brook, Penobscot River, Me	Atlantic salmon, landlocked salmon, humpback salmon, brook trout.
Staceyville, Upper Penobscot River, Me	Atlantic salmon.
Havre de Grace, Susquehanna River, Md	Shad, yellow perch, white perch.
Bryans Point, Potomac River, Md	Shad, yellow perch.
Edenton, Albemarle Sound, N. C	Shad.
Weldon, Roanoke River, N. C	Striped bass.
Washington, D. C., Potomac River	Shad, yellow perch, white perch, etc.

In order to counteract the effect of the very exhausting fisheries of the Great Lakes, the Government has for many years maintained hatcheries in that region, and in 1908 operated 6 belonging to the United States and 2 belonging to the State of Michigan. The fishes to which attention is given are those which enter most largely into the catch of the fishermen, namely, the whitefish, cisco, lake trout, and pike perch, the annual output of which now exceeds one and one-half billions. Under arrangement with the Canadian authorities, 2 egg-collecting stations for whitefish, cisco, and lake trout are maintained at points in Ontario.

HATCHERIES ON THE GREAT LAKES.

Location.	Fishes handled.
Cape Vincent, Lake Ontario, N. Y	Whitefish, lake trout, brook trout, steelhead, landlocked salmon, pike perch, yellow perch.
Put-in Bay, Lake Erie, Ohio	Whitefish, lake cisco, lake trout, pike perch.
Kelleys Island, Ohio [a]	Whitefish.
Middle Bass Island, Ohio [a]	Whitefish.
Monroe Piers, Mich.[a]	Whitefish, pike perch.
North Bass Island, Ohio [a]	Whitefish, lake cisco.
Pelee Island, Ontario (Canada) [a]	Whitefish, lake cisco.
Port Clinton, Ohio [a]	Whitefish, lake cisco, pike perch.
Toledo, Ohio [a]	Pike perch.
Northville, Mich.[b]	Lake trout, etc.
Alpena, Lake Huron, Mich	Whitefish, lake trout.
Beaver Island, Lake Michigan, Mich.[a]	Lake trout.
Charlevoix, Lake Michigan, Mich	Whitefish, lake trout.
Detroit, Detroit River, Mich.[c]	Whitefish, pike perch.
Algonac, Lake Huron, Mich.[a]	Pike perch.
Bay City, Lake Huron, Mich.[a]	Pike perch.
Belle Isle, Detroit River, Mich.[a]	Whitefish.
Grassy Isle, Detroit River, Mich.[a]	Whitefish.
Sault Ste. Marie, St. Marys River, Mich.[c]	Whitefish, lake trout.
Duluth, Lake Superior, Minn	Whitefish, lake trout, pike perch, etc.
Isle Royale, Mich.[a]	Lake trout.
Keweenaw Point, Mich.[a]	Lake trout.
Marquette, Mich.[a]	Lake trout.
Ontonagon, Mich.[a]	Lake trout.
Rossport, Ontario (Canada) [a]	Lake trout.

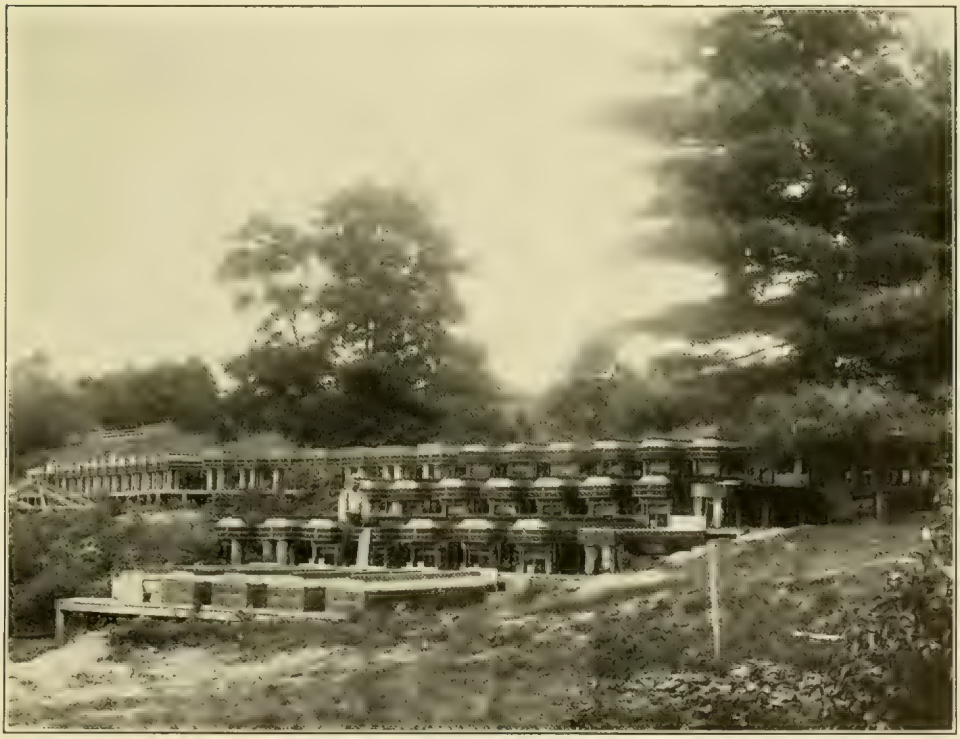
[a] Egg-collecting stations.

[b] Interior station, headquarters of the fish-cultural work in Michigan, conveniently located, and place where most of the lake-trout eggs are hatched.

[c] Hatcheries belonging to State of Michigan, leased by Bureau of Fisheries.

The hatcheries on the rivers and lakes of the Pacific coast region are devoted almost exclusively to the various salmons. In California, where the Bureau established a salmon hatchery as early as 1872, there is one central or main station, at Baird, on the McCloud River, with important collecting and eyeing stations on two other tributaries of the Sacramento. In Oregon a central hatchery at Oregon City, on the Willamette River, has three subhatcheries on tributaries of the Columbia in Oregon and Washington and three subhatcheries

Collecting cod eggs on a fishing vessel. One source of cod eggs hatched at the New England stations is the catch of the market fishermen. Spawntakers board the fishing boats, overhaul the fish, and save the eggs of such as are ripe.



Open-air salmon-rearing troughs. These troughs are used at the Craig Brook (Maine) hatchery for rearing Atlantic and landlocked salmon.

on tributaries of the Rogue River, Oregon, in addition to several egg-collecting stations. The interests of the large salmon fisheries of the Puget Sound region are safeguarded by a hatchery on Baker Lake, on the Skagit River, Washington, with an important auxiliary at Birdsview. The two latest additions to the western salmon hatcheries are at Yes Bay and Afognak, in Alaska, at which points immense numbers of blueback or sockeye salmon are now being put forth. A significant feature of artificial propagation on the Pacific seaboard is that in the Columbia basin the hatching of the acclimatized shad has begun on a small scale, and in the Sacramento basin the cultivation of the acclimatized striped bass has commenced under conditions which indicate that more eggs of this species may be obtained in California than in any of the States to which the fish is native.

HATCHERIES ON THE PACIFIC COAST STREAMS AND LAKES.

Location.	Fishes handled.
Baird, Sacramento River, Cal	Chinook salmon.
Battle Creek, Cal.[a]	Chinook salmon.
Bouldin Island, Cal	Striped bass.
Mill Creek, Cal.[a]	Chinook salmon.
Yreka, Sacramento River, Cal.[b]	Rainbow trout.
Baker Lake, Wash	Chinook salmon, blueback salmon, humpback salmon, silver salmon.
Birdsview, Wash	Chinook salmon, blueback salmon, humpback salmon, silver salmon, steelhead trout.
Oregon City, Willamette River, Oreg	Chinook salmon, silver salmon, steelhead trout, etc.
Big White Salmon, Columbia River, Wash	Chinook salmon.
Eagle and Tanner creeks, Columbia River, Oreg.[a]	Chinook salmon.
Eagle Creek, Clackamas River, Oreg.[b]	Steelhead trout.
Little White Salmon, Columbia River, Wash	Chinook salmon.
Rogue River, Oreg	Chinook salmon, steelhead trout, silver salmon.
Applegate Creek, Oreg.[b]	Chinook salmon, steelhead trout, silver salmon.
Findley Eddy, Rogue River, Oreg	Chinook salmon, silver salmon.
Illinois River, Rogue River, Oreg	Chinook salmon, steelhead trout.
Willamette Falls, Willamette River, Oreg	Shad.
Yes Bay, Yes Lake, Alaska	Blueback salmon.
Afognak, Afognak Island, Alaska	Blueback salmon.

[a] Stations where eggs are collected and eyed. [b] Collecting stations.

The hatcheries in the interior regions constitute the most numerous class, and their output reaches the largest number of people. Their operations are addressed chiefly to the so-called "game" fishes, which, while caught mostly by anglers, nevertheless constitute an important element of the food supply. At these stations large numbers of fish are reared to the fingerling or yearling sizes before being released; for which purpose more or less extensive pond areas are required.

A peculiar kind of station which is included in this general class is that devoted to the collection of fishes of various kinds obtained from the overflows in the upper Mississippi Valley. In the lowlands along the streams in this region the spring floods receding leave disconnected sloughs and pools, which either become dry during the summer or, if they remain until the winter, freeze solid, and the immense numbers of bass, crappy, and other desirable species therein are lost in the ordinary course of events. By seining these waters the Bureau obtains large numbers of fish that would otherwise perish, returning some of them to their native streams and distributing others to adjacent waters. In the autumn of 1908 six cars were employed in moving the fishes thus rescued.

The following table, giving the interior fish-cultural stations and their auxiliaries, shows that in 1908 there were operated 23 of these stations and substations where hatching operations were conducted and 21 others where eggs or fish were simply collected:

HATCHERIES IN INTERIOR STATES.

Location.	Fishes handled.
Bozeman, Mont	Brook trout, rainbow trout, black-spotted trout, golden trout, steelhead trout, landlocked salmon.
Redrock, Mont	Grayling.
Bullochville, Ga	Black basses, sunfishes, rock bass, catfish, etc.
Erwin, Tenn	Black basses, sunfishes, rock bass, yellow perch, rainbow and brook trouts, catfish, and minor species.
Green Lake, Me	Landlocked salmon, brook trout.
Branch Pond, Me.[a]	Landlocked salmon, brook trout.
Grand Lake Stream, Me	Landlocked salmon, brook trout.
Leadville, Colo	Rainbow trout, golden trout, black-spotted trout, brook trout, landlocked salmon, grayling.
Cheesman Lake, Colo.[a]	Rainbow trout.
Darrah, Colo.[a]	Brook trout.
Edith Lake, Colo.[a]	Brook trout.
Eldora Lake, Colo.[a]	Brook trout.
Englebrecht Lake, Colo.[a]	Brook trout.
Grand Lake, Colo	Black-spotted trout.
Grand Mesa Lakes, Colo	Black-spotted trout, rainbow trout, brook trout.
Musgrove Lake, Colo.[a]	Brook trout.
Ridgway Lake, Colo.[a]	Brook trout, rainbow trout.
Twin Lakes, Colo.[a]	Brook trout.
Wellington Lake, Colo.[a]	Brook trout.
Zoebles Lake, Colo.[a]	Brook trout.
Mammoth Spring, Ark	Black basses, rock bass.
Manchester, Iowa	Black basses, crappies, sunfishes, rock bass, pike perch, yellow perch, brook trout, lake trout, rainbow trout, black-spotted trout, catfish.
Bellevue, Iowa [b]	Large-mouth black bass, crappies, sunfishes, yellow perch, fresh-water drum, buffalo-fish, catfish.
La Crosse, Wis.[b]	Large-mouth black bass, crappies, sunfishes, rock bass, yellow perch, white bass, pike, buffalo-fish, catfish.
North McGregor, Iowa [b]	Large-mouth black bass, crappies, sunfishes, yellow perch, drum, pike, buffalo-fish, catfish.

[a] Stations for the collection of eggs.

[b] Stations for the rescue of young and adult fishes from overflowed lands of Mississippi River and tributaries.

Artificial spawning pond and raceway, used in culture of rainbow trout at the Wytheville (Virginia) station.

Interior of a typical trout hatchery.

HATCHERIES IN INTERIOR STATES—Continued.

Location.	Fishes handled.
Nashua, N. H.	Lake trout, brook trout, Sunapee trout, rainbow trout, hybrid trout, landlocked salmon, chinook salmon, small-mouth black bass.
Cumberland Center, N. H.[a]	Brook trout.
Lake Sunapee, N. H.[b]	Brook trout, Sunapee trout.
Neosho, Mo.	Black basses, crappies, sunfishes, rock bass, rainbow trout.
Northville, Mich.[c]	Brook trout, Loch Leven trout, steelhead trout, small-mouth black bass, and minor species.
Quincy, Ill.	Pike perch, black bass, and minor species.
Meredosia, Ill.[d]	Large-mouth black bass, crappies, sunfishes, pike perch, yellow perch, catfish, and minor species.
St. Johnsbury, Vt.	Small-mouth black bass, landlocked salmon, steelhead trout, lake trout, brook trout.
Arlington, Vt.	Brook trout.
Chittenden, Vt.[b]	Brook trout.
Darling Pond, Vt.[b]	Brook trout.
Lake Mansfield, Vt.[b]	Brook trout.
Lake Mitchell, Vt.[b]	Brook trout.
Swanton, Vt.	Pike perch, yellow perch.
San Marcos, Tex.	Large-mouth black bass, crappies, sunfishes, rock bass, warmouth bass.
Spearfish, S. Dak.	Rainbow trout, black-spotted trout, Loch Leven trout, brook trout.
Schmidts Lake, S. Dak.[b]	Brook trout.
Yellowstone Park, Wyo.	Black-spotted trout.
Tupelo, Miss.	Large-mouth black bass, sunfishes, yellow bass.
White Sulphur Springs, W. Va.	Black basses, rainbow trout, black-spotted trout, brook trout.

[a] Stations where eggs are collected and eyed but not hatched.
[b] Stations for the collection of eggs.
[c] See also in list of Great Lakes hatcheries.
[d] Stations for the rescue of young and adult fishes from overflowed lands of Mississippi River and tributaries.

THE OUTPUT AND ITS DISTRIBUTION.

The fish-cultural work of the Federal Government has now attained a magnitude that can not readily be comprehended, and is increasing at an exceedingly rapid rate. Especially marked has been the increase in the hatchery product during the past ten years, owing in part to the establishment of new stations, in part to the extension of operations at existing stations, and in part to greater efficiency of methods and appliances. The work during the fiscal year ending June 30, 1908, reached larger proportions than ever before, notwithstanding a shrinkage in the operations addressed to several important species. In the following summary by species of the eyed eggs, fry, and fingerlings, yearlings, and adults distributed in the past year it will be noted that several fishes included in the list of species cultivated do not appear in this table, for the reason that the entire stock was retained for breeding purposes. Ornamental species are likewise omitted from the table.

SUMMARY OF DISTRIBUTION OF FISH AND EGGS DURING THE FISCAL YEAR 1908.

Species.	Eggs.	Fry.	Fingerlings, yearlings, and adults.	Total.
Catfish			277, 601	277, 601
Carp			350	350
Buffalo-fish			40, 500	40, 500
Shad	760, 000	79, 316, 600		80, 076, 600
Whitefish	139, 266, 000	384, 480, 000		523, 746, 000
Lake cisco	12, 790, 000	3, 200, 000		15, 990, 000
Chinook salmon	68, 385, 550	24, 998, 185	2, 231, 797	95, 615, 532
Silver salmon	296, 000	13, 420, 714	57, 932	13, 774, 646
Blueback salmon	75, 000	69, 883, 305		69, 958, 305
Humpback salmon		7, 185, 748		7, 185, 748
Steelhead trout	333, 725	1, 123, 146	59, 000	1, 515, 871
Rainbow trout	830, 000	253, 650	2, 713, 600	3, 797, 250
Atlantic salmon		2, 079, 514	30, 003	2, 109, 517
Landlocked salmon	190, 000	441, 281	151, 526	782, 807
Black-spotted trouts	768, 380	4, 230, 540	1, 442, 376	6, 441, 296
Loch Leven trout			55, 012	55, 012
Lake trout	2, 734, 000	25, 267, 078	3, 182, 080	31, 183, 158
Brook trout	1, 473, 400	6, 307, 048	3, 471, 292	11, 251, 740
Sunapee trout		191, 736		191, 736
Grayling	200, 000	1, 047, 000		1, 247, 000
Pikes			17, 550	17, 550
Crappy and strawberry bass			200, 268	200, 268
Rock bass			25, 090	25, 090
Warmouth bass			1, 638	1, 638
Small-mouth black bass		232, 312	78, 940	311, 252
Large-mouth black bass		23, 900	588, 047	611, 947
Sunfishes			202, 810	202, 810
Pike perch	218, 725, 000	193, 438, 000		412, 163, 000
Yellow perch	2, 080, 000	382, 576, 000	68, 045	384, 724, 043
Striped bass		4, 333, 500		4, 333, 500
White perch	5, 740, 000	321, 670, 000		327, 410, 000
White bass			500	500
Fresh-water drum			26, 000	26, 000
Cod	3, 000, 000	235, 365, 000		238, 365, 000
Pollock		66, 454, 000		66, 454, 000
Tautog		794, 000		794, 000
Flatfish		389, 642, 000		389, 642, 000
Lobster		180, 932, 000	1, 011	180, 933, 011
Total	457, 647, 055	2, 398, 886, 257	14, 922, 968	2, 871, 456, 380

While the Bureau does not lay undue stress on mere numbers and considers the vitality of the fish and the conditions under which they are planted as of paramount importance, the foregoing figures are certainly very suggestive; and as a further statement of the magnitude of the fish-cultural work it may be of interest to record that the aggregate output of the hatcheries from 1872 to 1908 was about 22,365,200,000, of which about 10,341,700,000 represents the work of the past five years.

The first consideration in the distribution of fishes is to make ample return to the waters from which eggs or fish have been collected. The remainder of the product is consigned to suitable public or private waters. All applications

for fish for private waters and many of those for public streams and lakes are transmitted through and receive the indorsement of a United States Senator or Representative. The fish are carried to their destination in railroad cars or by messengers who accompany the shipments in baggage cars. During the fiscal year 1908 the Bureau received 8,284 applications for fish, nearly all for game species. The demand, especially for the basses, crappies, and catfishes, is greater than can be met with present resources.

Fishes are distributed at various stages of development, according to the species, the numbers in the hatcheries, and the facilities for rearing. The commercial fishes, hatched in lots of many millions, are necessarily planted as fry. It is customary to distribute them just before the umbilical sac is completely absorbed. Atlantic salmon, landlocked salmon, and various species of trout, in such numbers as the hatchery facilities permit, are reared to fingerlings from 1 to 6 inches in length; the remainder are distributed as fry. The basses and sunfishes are distributed from the fish-cultural stations and ponds from some three weeks after they are hatched until they are several months of age. When the last lots are shipped the basses usually range from 4 to 6 inches and the sunfishes from 2 to 4 inches in length. The numerous fishes collected in overflowed lands—basses, crappies, sunfishes, catfishes, yellow perch, and others—are 2 to 6 inches in length when taken and distributed. Eggs are distributed only to state hatcheries or to applicants who have hatchery facilities.

To insure the best results from plants of fish, applicants are required to furnish full information as to the physical characters and present inhabitants of the waters to be stocked, and the suitable species is determined by the Bureau; black bass, for instance, are not furnished for waters stocked with trout, which they would destroy, nor are trout consigned to waters already inhabited by predaceous fishes. The number of fish allotted to any applicant is governed by the available supply of that species, and the area and character of the water in question. Some species, merely hatched and not reared, can, as above stated, be produced by the hundred million. The allotments of these fry are correspondingly large. The species reared at the hatcheries or collected from overflows are available in no such numbers, and 200 or 300 fingerlings of these would be all that could be supplied as compared with half a million of the other fry. Species that are distributed as fry and also reared are of course supplied in much larger numbers as fry than as fingerlings. The Bureau attempts only to furnish a liberal brood stock, expecting that the fish will be protected until they have had time to reproduce.

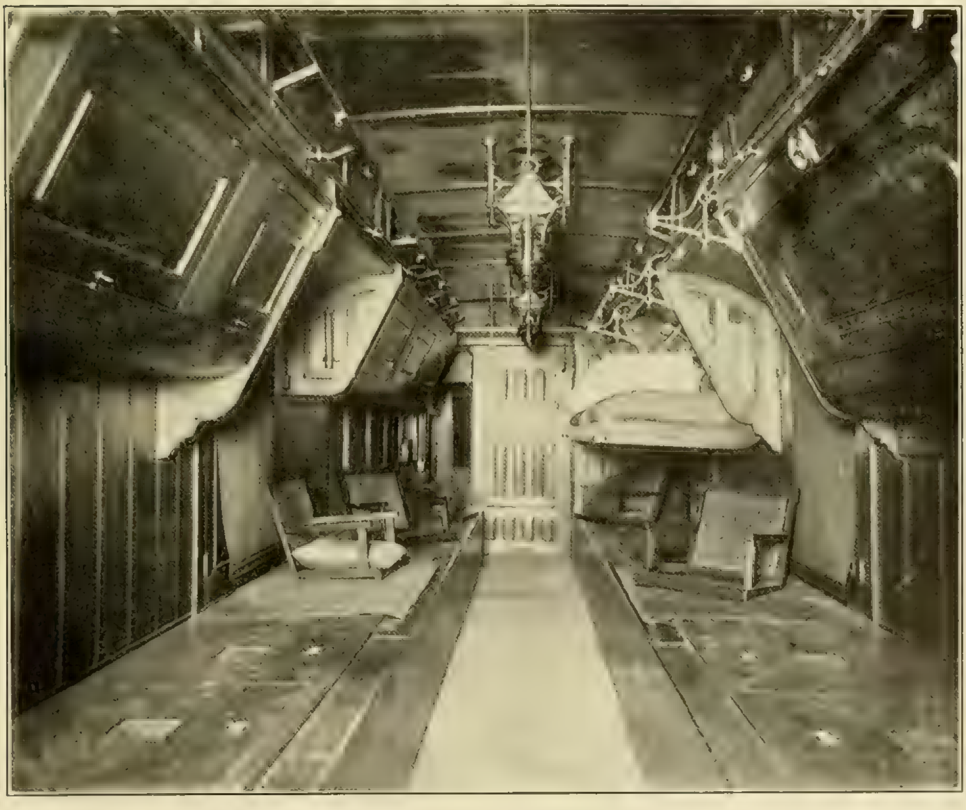
Fish are delivered to applicants free of charge at the railroad station nearest the point of deposit, and for this purpose is maintained a special car and messenger service, which is one of the most important branches of the fish-cultural work. In the early days baggage cars were employed, but these

have now been supplanted by an equipment which not only affords more comfort to fish and attendants, but makes it possible to transport the fish much greater distances and with smaller percentage of loss. The cars, of which there are now 6, are of standard size, and are attached to regular express and local passenger trains. Each car has 20 or more large water tanks along the sides in which to carry fish, compartments holding more than 1,000 gallons of reserve water, a boiler room, and a plant for pumping both water and air into the fish tanks. There are also an office, kitchen, pantries, refrigerator, and 6 Pullman sleeping berths, with other facilities for the convenience and comfort of the crew of 5 men (including a cook) who live on the car throughout the year. The Government furnishes the cook, fuel, and utensils, but the men provide their own food. For small shipments of fish and for supplying places off the main railway lines messengers detached from the cars carry fish in 10-gallon cans in baggage cars. The distributions last year required travel amounting to 83,840 miles by the cars, and 263,196 miles by detached messengers—a total of 347,036 miles—of which 11,826 for cars and 80,816 for messengers were furnished by the railroads free of charge.

POPULARITY OF THE WORK.

There are few enterprises undertaken by the United States Government that are more popular, meet with more general and generous support, and have contributed more to the prosperity and happiness of a larger number of people than the federal fish-cultural work, evidence of which fact is afforded by the attitude and action of Congress. The comparatively large budget for the various branches of the Bureau's work is voted each year without any opposition whatever, and the appropriations are increasing yearly. When special needs arise and their merit is presented to Congress, special appropriations can usually be obtained; and government fish culture is so popular in the country at large and the demand for new hatcheries is so widespread that an extraordinary number of hatchery bills have been introduced and favorably considered in recent sessions of Congress. The Bureau advocates the building of new hatcheries as one of the best and most remunerative measures that can possibly be undertaken by the Federal Government, but it rarely has to take the initiative, and on several occasions the establishment of a hatchery has been proposed by Congress before the necessity for it has actually developed. During each of the recent sessions of Congress had all the bills providing for new hatcheries become laws the Bureau would have been seriously handicapped in designing and constructing the new buildings and ponds and in supplying competent persons to operate them. In the first session of the Sixtieth Congress, which began in December, 1907, and ended in May, 1908, there were introduced 101 distinct bills, carrying an aggregate appropriation of $2,142,000, and providing for 74 hatcheries and 4 laboratories in 43 States and Territories.

A fish transportation car. Six cars of this kind are in constant use by the Bureau. Live fish are carried safely for long distances, and eggs may be incubated while on trains traveling 60 miles an hour.



Interior view of fish transportation car, showing rows of covered tanks where fish are carried and Pullman sleeping berths for attendants.

While the manifold operations of the Bureau touch directly or indirectly practically the entire population of the United States, they appeal with special force to the commercial fisherman, the fish dealer, the amateur angler, the student of aquatic biology and physics, the owner of small ponds, lakes, or streams. and the professional cultivator of fishes and other water products.

SCIENTIFIC INQUIRY.

The first duties undertaken by the Bureau after its organization involved biological investigations, and the operations up to the present time have continued to have a distinctly scientific basis. In making his original plans for the systematic investigation of the waters of the United States and the biological and physical problems they present, Commissioner Baird insisted that to study only the food fishes would be of little importance, and that useful conclusions must needs rest upon a broad foundation of investigations purely scientific in character. The life history of species of economic value should be understood from beginning to end, but no less requisite is it to know the histories of the animals and plants upon which they feed or upon which their food is nourished; the histories of their enemies and friends and the friends and foes of their enemies and friends, as well as the currents, temperatures, and other physical phenomena of the waters in relation to migration, reproduction, and growth.

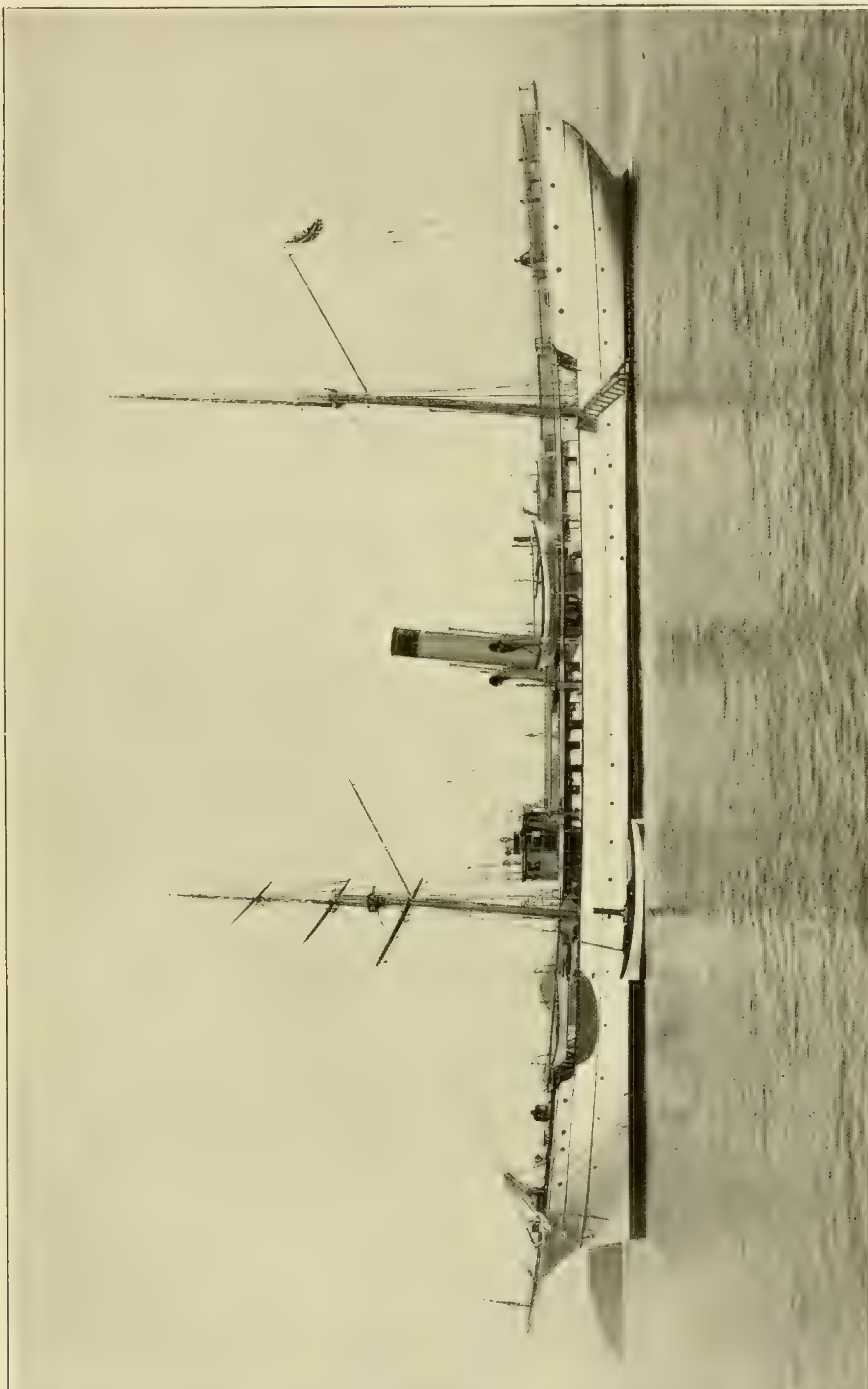
In pursuance of this policy the Bureau has secured the services of many prominent men of science, and much of the progress in the artificial propagation of fishes, in the investigation of fishery problems, and in the extension of knowledge of our aquatic resources has been due to men eminent as zoologists who have been associated with the work temporarily. Among such men recently have been Alexander Agassiz, Hermon C. Bumpus, Gary N. Calkins, Bashford Dean, Charles H. Gilbert, Theodore Gill, C. Judson Herrick, Francis H. Herrick, David Starr Jordan, A. D. Mead, George H. Parker, Jacob Reighard, Henry B. Ward, William M. Wheeler, and Henry V. Wilson. Their services have been the services of specialists for particular problems, and through them the Bureau has not only been able to give to the public the practical results of applied science, but has contributed to pure science valuable knowledge of all forms of aquatic life.

The small permanent staff of the Bureau concerns itself more directly with studies of fishes and their environment, with the conservation of diminishing commercial species, and the development of new or improved methods of increasing the supply. Such lines of work are undertaken as the need appears or as assistance is asked for, and keep the scientific assistants in the field for extended periods each year. The most important work in hand at present concerns aquatic products other than fishes—namely, oysters, fresh-water mussels,

sponges, and the diamond-back terrapin, in all of which cases the problem is to find means to offset the results of long-continued overdraft upon the natural supply. The Bureau has also the services of a fish pathologist—a position specially created by Congress at the solicitation of the commissioner. This assistant has devoted most of his time to the study of diseases among fishes at the hatcheries of the Government and of various States, and has added greatly to the existing knowledge of the causes and prevention of many of the affections which often prove so serious in fishes under cultivation. His field includes also the investigation of conditions due to pollution of waters.

Two seaside laboratories are maintained by the Bureau for the prosecution of investigations in pure and applied science. One of these is located at Woods Hole, Mass., the scene of the first biological work undertaken after the establishment of the Bureau. It was built in 1883, and is in conjunction with a marine fish hatchery. Here also are extensive wharves, at which the largest vessels may lie, and protected harbors for small craft. A large residence building at this station was for a number of years occupied as the summer headquarters of the Bureau, the entire executive and office force being transferred from Washington. The other laboratory is situated on a small island near Beaufort, N. C., and was constructed in 1901. The land for both of these stations was donated by private individuals. In addition to their function in the investigations of the Bureau itself, these laboratories are open to the public for study and scientific research. Students and professors in colleges and any other qualified investigators may have the facilities of the laboratories upon request, and these opportunities are largely availed of each year.

For the survey of offshore fishing grounds, the study of pelagic fishes, and the general exploration of the seas, the Bureau has had, since 1882, the steamer *Albatross*, which was specially designed and built for this work, and has contributed more to the knowledge of the life and physics of the sea than any other vessel. The *Albatross* is a twin-screw iron steamer, rigged as a brigantine, of 1,074 tons displacement and 384 net tonnage, and was built at a cost of $190,000, including original equipment. The complement of officers and men, numbering about 80, is furnished by the navy; there is in addition a small civilian staff, including a resident naturalist and a fishery expert, to whom the practical work of the ship is intrusted. After spending several years in the investigation of the fishing grounds of the Atlantic coast of North America, the *Albatross* was dispatched to the Pacific Ocean in 1888, and has since confined her operations to those waters. The vessel has made three extended cruises to the southern and eastern parts of the Pacific, several cruises to the Hawaiian Islands and Japan, and many visits to Alaska, in addition to numerous surveys on the coast of the Pacific States, all having for their object the investigation of the physics and biology of the regions visited, the determination of their aquatic resources,



Deep-sea exploring steamer Albatross, built by the Bureau and for twenty-five years engaged in surveying fishing grounds and in deep-sea exploration in the Atlantic and Pacific oceans. The Albatross has contributed more to the knowledge of marine biology than has any other vessel.

and the study of their fisheries. In 1907 the vessel began a biological survey of the waters of the Philippine Archipelago, and is now engaged on that work. The deepest sounding made by the *Albatross*—near the island of Guam—was 4,813 fathoms; the greatest depth at which the vessel found life was 4,173 fathoms; the greatest known ocean depth is 5,269 fathoms, near Guam, ascertained by the U. S. S. *Nero* while using *Albatross* apparatus.

Work similar to that done by the *Albatross* is conducted by the steamer *Fish Hawk* on the Atlantic coast. This vessel, built for the Bureau in the winter of 1879–80, is of 441 gross tons burden, and has a naval crew of 45 men; it is equipped for sounding and dredging, and has recently been employed chiefly in the exploration of the coastal waters and inshore fishing grounds of New England while attached to the laboratory at Woods Hole. The vessel is convertible into a hatchery, and has been engaged in the hatching of shad and other fishes along the entire coast from Maine to Texas.

The Bureau's large collections of natural-history specimens are deposited in the United States National Museum. The duplicates, however, are not retained by that institution, but are distributed upon request to public schools and colleges. In this way hundreds of thousands of specimens representing all groups of aquatic animals have been supplied for educational purposes.

STATISTICS AND METHODS OF THE FISHERIES.

The first duty to which the Bureau of Fisheries was assigned, namely, the investigation of the reported decrease of food fishes in New England, necessarily involved the collection of statistics of production, personnel, and capital. Since that time this branch of the work has been conducted without interruption, and in it have naturally been included the various other subjects affecting the economic and commercial aspects of the fisheries. Among its functions are (1) a general survey of the commercial fisheries of the country; (2) a study of the fishery grounds with reference to their extent, resources, yield, and condition; (3) a study of the vessels and boats employed in the fisheries, with special reference to their improvement; (4) a determination of the utility and effect of the apparatus of capture employed in each fishery; (5) a study of the methods of fishing, for the special purpose of suggesting improvements or of discovering the use of unprofitable or unnecessarily destructive methods; (6) an inquiry into the methods of utilizing fishery products, the means and methods of transportation, and the extent and condition of the wholesale trade; (7) a census of the fishing population, their economic and hygienic condition, nativity, and citizenship; (8) a study of international questions affecting the fisheries; (9) the prosecution of inquiries regarding the fishing apparatus and methods of foreign countries.

The collection of statistics of the commercial fisheries and the industries dependent thereon constitutes the major part of this work. The information is required in great detail, and is obtained by the personal inquiries of a small corps of agents, who visit all the fishing communities and interview fishermen, fish dealers, vessel owners, factory proprietors, and others. While the Bureau is not authorized by law to enforce demands for data, it very rarely happens that information is refused; on the contrary, the objects and value of the work being now well understood, many thousands of fishermen keep accurate records for the special use of the Bureau, and dealers, transportation companies, preparators, etc., permit free access to their books.

The relatively small force available for the collection of statistics, the magnitude of the territory to be covered, and the extent of the fisheries prevent the canvass of more than one section of the country during one season; and it has been found impossible to cover the entire coastwise and interior fisheries oftener than once in four or five years. Herewith are the latest available statistics gathered by the Bureau for the general fishing industry. These figures show that 219,534 persons were engaged in the fisheries, $94,254,839 were invested in vessels, boats, apparatus, and other property, and the products had a value of $61,047,909:

Statement of the Persons Engaged and the Capital Invested in the Fisheries of the United States.

Item.	Atlantic and Gulf States.		Pacific Coast States and Alaska.	
	Number.	Value.	Number.	Value.
Persons employed	161,923		32,410	
Vessels fishing	4,584	$8,170,256	121	$621,017
Tonnage	85,432		8,250	
Outfit		3,006,425		289,897
Vessels transporting	1,686	1,847,469	334	2,771,022
Tonnage	29,737		62,255	
Outfit		295,257		68,055
Boats	61,489	3,981,761	10,155	1,528,911
Seines	3,888	534,227	772	282,244
Gill nets and trammel nets	143,824	782,338	8,611	1,095,282
Pound nets, trap nets, and weirs	7,384	1,540,835	680	1,444,510
Fyke nets	19,033	94,180	446	4,610
Beam trawls and paranzellas	66	1,696	41	6,371
Wheels and slides	37	775	49	168,000
Eel and lobster pots	228,086	248,974		
Dredges, tongs, rakes, scrapes, etc		411,424		7,131
Lines		347,079		44,421
Other apparatus		55,347		45,075
Shore and accessory property		20,571,131		10,473,781
Cash capital		15,013,676		7,205,650
Total		56,902,850		26,055,977

Trial fishing on the Albatross. This experimental catch of cod and halibut was taken in twenty minutes by the Albatross while exploring a new "bank" off the coast of Alaska. (See p. 1384.)

Marine biological laboratory at Beaufort, N. C. This station, built in 1901, is favorably located for the study of the aquatic fauna of the southeast coast. The laboratory building is 174 feet long and 42 feet wide in the main portion, has a large museum and aquaria, and accommodates about 30 workers. Adjoining the laboratory building are a power plant and a mess house and kitchen. (See p. 1384.)

STATEMENT OF THE PERSONS ENGAGED AND THE CAPITAL INVESTED IN THE FISHERIES OF THE UNITED STATES—Continued.

Item.	Great Lakes and interior waters.		Total.	
	Number.	Value	Number	Value.
Persons employed	25, 201		219, 534	
Vessels fishing	194	$634, 450	4, 899	$9, 425, 723
Tonnage	3, 506		97, 188	
Outfit		147, 402		3, 443, 724
Vessels transporting	18	69, 400	2, 038	4, 687, 891
Tonnage	500		92, 492	
Outfit		8, 154		371, 466
Boats	12, 156	529, 766	83, 800	6, 040, 438
Seines	992	76, 612	5, 652	893, 083
Gill nets and trammel nets	102, 604	657, 804	255, 039	2, 535, 424
Pound nets, trap nets, and weirs	4, 848	617, 063	12, 912	3, 602, 408
Fyke nets	40, 724	261, 379	60, 203	360, 169
Beam trawls and paranzellas			107	8, 067
Wheels and slides	4	480	90	169, 255
Eel and lobster pots			228, 086	248, 974
Dredges, tongs, rakes, scrapes, etc		13, 683		432, 238
Lines		24, 994		416, 494
Other apparatus		16, 215		116, 637
Shore and accessory property		4, 809, 022		35, 853, 934
Cash capital		3, 429, 588		25, 648, 914
Total		11, 296, 012		94, 254, 839

NOTE.—The years to which these figures pertain are 1905 for New England, 1904 for the Middle Atlantic States 1902 for the South Atlantic and Gulf States, 1904 for the Pacific States, 1907 for Alaska, 1903 for all interior waters.

STATEMENT OF THE PRODUCTS OF THE FISHERIES OF THE UNITED STATES.

Product.	Atlantic and Gulf States.		Pacific States and Alaska.	
	Pounds.	Value.	Pounds.	Value.
Fishes:				
Alewives	52, 061, 580	$473, 811		
Barracudas	35, 435	1, 253	2, 159, 282	$51, 820
Black basses	1, 201, 135	90, 956	93, 500	2, 910
Bluefish	16, 575, 661	781, 802		
Bonito	1, 019, 032	41, 818	212, 062	3, 075
Buffalofishes	3, 006, 610	26, 556		
Butterfish	4, 184, 363	138, 761		
Catfishes	5, 252, 858	168, 102	923, 144	27, 292
Cods	77, 498, 674	2, 101, 119	7, 694, 944	193, 966
Crappy and strawberry bass	253, 506	7, 154		
Croaker	6, 910, 903	138, 931	121, 340	3, 145
Cusk	9, 079, 866	139, 964		
Drum, fresh-water	5, 550	131		
Drum, salt-water	4, 063, 230	109, 055		
Eels	3, 636, 964	212, 160		
Flounders	9, 676, 172	290, 186	8, 418, 145	155, 512
German carp	1, 328, 271	78, 778	90, 374	1, 607
Haddock	77, 065, 441	1, 258, 763		
Hakes	35, 928, 627	419, 384		
Halibut	3, 715, 776	237, 876	12, 091, 000	358, 930
Herrings	83, 390, 554	692, 854	4, 455, 729	35, 407
Mackerel	16, 323, 612	1, 106, 741	134, 992	3, 666
Menhaden	562, 427, 449	1, 452, 062		

STATEMENT OF THE PRODUCTS OF THE FISHERIES OF THE UNITED STATES—Continued.

Product	Atlantic and Gulf States.		Pacific States and Alaska	
	Pounds.	Value.	Pounds.	Value
Fishes—Continued.				
Mullets	41, 734, 178	$709, 067	12, 952	$423
Perch, white	2, 674, 763	160, 875		
Perch, yellow	587, 885	25, 547		
Pike perches	31, 200	1, 505		
Pike and pickerel	154, 359	10, 045		
Pollock	29, 033, 093	305, 436		
Pompano	876, 305	56, 905	33, 850	4, 502
Rockfishes			1, 896, 467	63, 409
Salmons	86, 368	20, 161	267, 389, 335	12, 589, 958
Scup	9, 216, 731	250, 320		
Sea bass	4, 282, 313	183, 219		
Shads	28, 065, 130	1, 688, 352	489, 505	13, 146
Sheepshead	2, 634, 046	68, 060		
Silver hake	5, 549, 935	37, 866		
Smelts	628, 860	69, 710	2, 762, 202	79, 973
Snapper, red	13, 763, 653	418, 360		
Snappers, other	401, 349	11, 419		
Spanish mackerel	2, 965, 381	160, 270	708, 465	11, 704
Spot	2, 023, 476	65, 759		
Squeteagues	43, 794, 980	1, 233, 959	988, 524	31, 548
Striped bass	2, 601, 354	259, 926	1, 570, 404	92, 116
Sturgeons	1, 475, 925	137, 311	137, 981	4, 271
Suckers	451, 426	17, 364		
Sunfishes	751, 655	18, 757	11, 343	554
Swordfish	3, 311, 369	205, 567		
Tautog	847, 756	28, 298		
Trouts			3, 089, 670	129, 253
Whiting and kingfish	1, 178, 650	56, 107		
Other fishes	8, 245, 417	210, 136	3, 748, 766	74, 186
Fish oil	26, 325	856	718, 837	19, 191
Mollusks:				
Abalone			824, 948	9, 155
Clams, hard-shell	8, 193, 844	1, 320, 364	871, 008	65, 078
Clams, soft-shell and other	8, 130, 430	543, 722	308, 080	30, 280
Cockles, winkles, conchs, etc	93, 734	13, 510		
Mussels	1, 551, 850	6, 705	28, 215	1, 764
Oysters	215, 121, 914	17, 417, 581	2, 665, 696	1, 031, 523
Oyster and other shells	19, 975, 115	20, 488	8, 730	218
Scallops	1, 586, 151	297, 658		
Squid	1, 119, 369	17, 307	251, 360	10, 054
Crustaceans:				
Crabs	34, 137, 937	723, 845	6, 081, 606	181, 904
Crawfish	16, 000	615	187, 200	12, 480
King crabs	2, 303, 000	8, 903		
Lobster	11, 898, 136	1, 364, 721		
Shrimp and prawn	16, 186, 905	288, 344	1, 311, 750	93, 544
Shrimp shells			950, 000	4, 390
Spiny lobsters	55, 664	3, 282	1, 078, 065	43, 406
Reptiles and batrachians:				
Alligator hides	349, 927	40, 779		
Frogs	9, 210	1, 289		
Terrapins and turtles	856, 936	94, 586	28, 095	2, 616
Mammals:				
Fur-seal pelts			92, 364	484, 649
Hair-seal pelts			75, 417	13, 354
Otter pelts	3, 283	18, 367	3, 562	16, 703
Whalebone	55, 950	193, 037	120, 191	529, 614
Whale oil	3, 933, 554	246, 565	408, 419	20, 796

STATEMENT OF THE PRODUCTS OF THE FISHERIES OF THE UNITED STATES—Continued.

Product.	Atlantic and Gulf States.		Pacific States and Alaska.	
	Pounds.	Value.	Pounds.	Value.
Mammals—Continued.				
Ambergris	94	$16,900		
Sea-elephant oil	590,625	25,000		
Sea-elephant skins	5,000	600		
Walrus products			8,749	$5,771
Minor products			7,575	7,791
Miscellaneous:				
Sponges	346,889	364,422		
Seaweeds	841,000	34,120	59,320	2,267
All other products	2,886,040	39,926	1,198,589	34,380
Total	1,512,283,708	39,482,010	336,521,752	16,553,301

Product.	Great Lakes and interior waters.		Total.	
	Pounds.	Value.	Pounds.	Value.
Fishes:				
Alewives			52,061,580	$473,811
Barracudas			2,194,717	53,073
Black basses	644,936	$56,605	1,939,571	150,471
Bluefish			16,575,661	781,802
Bonito			1,231,094	44,893
Buffalofishes	11,527,531	313,841	14,534,141	340,397
Butterfish			4,184,363	138,761
Catfishes	6,542,001	336,135	12,718,003	531,529
Cods			85,193,618	2,295,085
Crappy and strawberry bass	1,143,800	54,034	1,397,306	61,188
Croaker			7,032,243	142,076
Cusk			9,079,866	139,964
Drum, fresh-water	3,507,331	87,810	3,512,881	87,941
Drum, salt-water			4,063,230	109,055
Eels	178,952	11,409	3,815,916	223,569
Flounders			18,094,317	445,698
German carp	17,524,118	361,870	18,942,763	442,255
Haddock			77,065,441	1,258,763
Hakes			35,928,627	419,384
Halibut			15,806,776	596,806
Herrings			87,846,283	728,261
Herring, lake	32,177,689	816,046	32,177,689	816,046
Mackerel			16,458,604	1,110,407
Menhaden			562,427,449	1,452,062
Mullets			41,747,130	709,490
Paddlefish	1,432,257	53,565	1,432,257	53,565
Perch, white			2,674,763	160,875
Perch, yellow	6,492,885	156,727	7,080,770	182,274
Pike perches	10,868,404	456,470	10,899,604	457,975
Pike and pickerel	1,296,911	69,677	1,451,270	79,722
Pollock			29,033,093	305,436
Pompano			910,155	61,407
Rockfishes			1,896,467	63,409
Salmons	125,858	5,629	267,601,561	12,615,748
Scup			9,216,731	250,320
Sea bass			4,282,313	183,216
Shads	8,750	875	28,563,385	1,702,373
Sheepshead			2,634,046	68,060
Silver hake			5,549,935	37,866

STATEMENT OF THE PRODUCTS OF THE FISHERIES OF THE UNITED STATES—Continued.

Product.	Great Lakes and interior waters.		Total.	
	Pounds.	Value.	Pounds.	Value.
Fishes—Continued				
Smelts	23,600	$2,720	3,414,662	$152,403
Snapper, red			13,763,653	418,360
Snappers, other			401,349	11,419
Spanish mackerel			3,673,846	171,974
Spot			2,023,476	65,759
Squeteagues			44,783,504	1,265,507
Striped bass			4,171,758	352,042
Sturgeons	1,647,306	91,372	3,261,212	232,954
Suckers	9,087,213	178,940	9,538,639	196,304
Sunfishes	1,325,521	33,295	2,088,519	52,606
Swordfish			3,311,369	205,567
Tautog			847,756	28,298
Trouts	17,069,284	951,864	20,158,954	1,081,117
Whitefish	7,728,761	350,186	7,728,761	350,186
Whiting and kingfish			1,178,650	56,107
Other fishes	1,657,805	29,513	13,651,988	313,835
Fish oil			745,162	20,047
Mollusks:				
Abalone			824,948	9,155
Clams, hard-shell			9,064,852	1,385,442
Clams, soft-shell and other			8,438,510	574,002
Cockles, winkles, conchs, etc			93,734	13,510
Mussels			1,580,065	8,469
Mussel shells	51,856,430	530,098	51,856,430	530,098
Oysters			217,787,610	18,449,104
Oyster and other shells			19,983,845	20,706
Scallops			1,586,151	297,658
Squid			1,370,729	27,361
Crustaceans:				
Crabs			40,219,543	905,749
Crawfish	244,464	7,897	447,664	20,992
King crabs			2,303,000	8,903
Lobster			11,898,136	1,364,721
Shrimp and prawn	190,884	11,808	17,689,539	393,696
Shrimp shells			950,000	4,390
Spiny lobsters			1,133,729	46,688
Reptiles and batrachians:				
Alligator hides			349,927	40,779
Frogs	336,049	24,788	345,259	26,077
Terrapins and turtles	524,283	17,292	1,409,314	114,494
Mammals:				
Fur-seal pelts			92,364	484,649
Hair-seal pelts			75,417	13,354
Otter pelts	16	40	6,861	35,110
Whalebone			176,141	722,651
Whale oil			4,341,973	267,361
Ambergris			94	16,900
Sea-elephant oil			590,625	25,000
Sea-elephant skins			5,000	600
Walrus products			8,749	5,771
Minor products			7,575	7,791
Miscellaneous:				
Sponges			346,889	364,422
Seaweeds			900,320	36,387
All other products	24,200	2,092	4,108,829	76,398
Total	185,187,239	5,012,598	2,033,992,699	61,047,909

SUPPLEMENTARY TABLE SHOWING CERTAIN OF THE ABOVE PRODUCTS IN BUSHELS, GALLONS, AND NUMBER.

Product.		Quantity.
Clams, hard-shell	bushels	1, 133, 106
Clams, soft-shell and other	do	843, 851
Mussels	do	48, 946
Oysters	do	31, 112, 515
Oyster and other shells[a]	do	332, 910
Scallops	do	264, 358
Cockles and winkles	do	9, 400
Oil:		
Fish	gallons	99, 375
Whale	do	578, 930
Sea-elephant	do	78, 750
Fur-seal pelts	number	15, 394
Alligator hides	do	70, 410
Otter Skins	do	4, 537

[a] Exclusive of tortoise and mussel shells.

The two most important fishing ports on the Atlantic coast are Boston and Gloucester, from which places upward of 435 vessels, of 24,000 net tonnage, valued at $2,150,000 and carrying over 6,000 men, are employed in the fisheries. Most of the vessels are schooner rigged, and engaged in fishing on the high seas or on the "banks" lying off the United States and the British provinces. In the year 1907 about 200,000,000 pounds of fish, having a first value of over $5,250,000, were landed in the ports named. For the purpose of keeping in close touch with the condition and extent of these fisheries, which afford a good criterion of the New England fisheries as a whole, two local agents are employed to collect daily statistics of receipts, and this information is incorporated into a special bulletin issued monthly and widely distributed to the trade. It is the expectation that this local statistical service will be extended to other important centers.

The Bureau has conducted several investigations of the fisheries of the Hawaiian Islands and Porto Rico, and is now engaged in a study of the fisheries of the Philippine Islands. The latest information obtained gives the following figures for Hawaii and Porto Rico, for the Philippines no complete data are available, but it is estimated that the industry yields annually products to the value of $10,000,000 to $15,000,000.

Item.	Hawaii (1903).	Porto Rico (1902).
Persons engaged in fishing	3, 241	748
Value of vessels, boats, and apparatus employed	$309, 217	$35, 826
Quantity of catch (pounds)	6, 972, 735	2, 169, 770
Value of catch	$677, 897	$106, 022

ALASKA SALMON-INSPECTION SERVICE.

The fishing interests in Alaska, representing an investment of $9,000,000 and yielding last year a product valued at more than $10,000,000, have received especial attention from the Government ever since the Territory was acquired, in 1867. The seal fisheries, at first considered the most valuable sources of revenue, were at once placed under protective legislation. Later there appeared a similar need of regulation of the salmon fisheries, which have now come to support industries many times more valuable than the seal fisheries and standing in large proportion to the total fishing interests of the whole United States. The Alaska salmon-inspection service has thus grown to be one of the most important branches of Government fishery work, and it is one of the few instances where the Government has assumed legislative powers over fishing.

Supervision of the salmon fisheries, as of the seal, was at first given to the Treasury Department, and it remained under that jurisdiction until 1903, when it was transferred to the Department of Commerce and Labor, by which it is administered through the Bureau of Fisheries. There are three agents in this field, whose duty it is to inquire into the methods by which fish are caught, prepared, and marketed, and into the conditions of supply, to report thereon and recommend legislation, and to enforce existing laws. For these purposes the entire region is canvassed every year, the agents remaining on the ground throughout the fishing season, from June to September.

The protection of the Alaska salmon fisheries has been a difficult problem. The unheard-of magnitude of the resources invited a corresponding recklessness and improvidence. As the canning industry developed, every device that could be used for wholesale capture of fish was put into operation, and gradually all of the favorite streams of the salmon became so blocked with seines, gill nets, traps, and barricades that but a small proportion of the fish could find passage to the spawning grounds, and the future supply was thus most seriously endangered. The Alaskan aborigines likewise conducted their fishing in a very destructive way, often placing impassable barriers in streams up which salmon were running, and, through ignorance or indifference, leaving the obstructions in place after the full supply of fish had been secured. It was soon apparent that the laws and regulations were inadequate to meet the special conditions prevailing and were of such a nature as to make their enforcement very difficult.

In 1903 a special commission was appointed to make exhaustive study of the natural history of the salmons of Alaska and to submit recommendations for an improved regulation of the fisheries. As a result a new code of laws is now in effect and promises to prevent the threatened decline in these enormous industries. With increased restrictions as to fishing methods, obstructions in streams, close seasons, etc., the Department of Commerce and Labor is empowered to

Alaskan fish traps and runs used by natives on Chilkoot Stream for obtaining their winter supply of salmon.

Salmon trap in an Alaskan river. This form of trap is extensively used in the Bristol Bay region, and takes immense quantities of salmon for the canneries. The largest traps have leaders more than half a mile long, and cost upward of $15,000.

set aside any streams as spawning preserves whenever such course shall be desirable, all fishing in such waters to be prohibited. A license tax is required on all salmon products; from the payment of this tax, however, all canning and salting establishments are exempted upon condition of their returning young salmon to the streams in the ratio of 1,000 fry to every 10 cases of salmon canned. Three private hatcheries, representing extensive canning interests, were in operation in 1907 and liberated a total of 119,000,000 young fish. The Government itself has undertaken extensive hatchery work, having now in operation a station at Yes Lake established in 1905 and one at Afognak Bay just completed. In the two years of its operations the Yes Bay hatchery has produced and liberated over 61,000,000 salmon fry.

The seal and salmon fisheries have hitherto overshadowed all other aquatic resources in Alaska, not only in commercial value but in revenue to the Government. The rental from the fur-seal islands alone has more than repaid the purchase price of the Territory, and the tax derived from the salmon fisheries now amounts to about $90,000 a year. Some long-neglected products are gradually coming into importance, however, and the cod, halibut, and herring fisheries especially have undergone remarkable development in the last few years. Since it became a part of the United States, Alaska has yielded fishery products amounting in value to $158,000,000, of which about $49,000,000 was derived from fur seals, $86,000,000 from salmon, and the remaining $23,000,000 from all other aquatic products. The sum paid by the United States to Russia for the Territory of Alaska was only $7,200,000.

RELATIONS WITH THE STATES AND WITH FOREIGN COUNTRIES.

From the beginning of its career the Bureau has maintained cordial relations with the fishery authorities of the various States. The policy has been to aid and supplement, never to supplant, the work of the States; and the field is so large and the objects in view have such importance and common interest that there should never arise cause for unfriendly rivalry. The cooperation in fish-cultural, biological, and fishery work has been extensive.

Twenty-seven of the States have hatcheries of their own, and to any of these the Bureau transfers eggs and fry when they are available and desired. This policy is not only an aid to the state work, but facilitates the hatching by relieving congestion at the government stations, and it also permits the most judicious planting of the fish. The Bureau has in a number of cases taken over and operated hatcheries owned by the States, and in others the egg collections are made conjointly. In the Pacific salmon work there was for years cooperation between the California Fish Commission and the Bureau, and much of the whitefish and pike perch work on Lake Erie has been done by the Bureau working with the States of Ohio and Pennsylvania.

In the States that have no means for undertaking fish-cultural work the Government is looked to for the stocking of both public and private waters; and, for that matter, the Bureau distributes young fish to applicants in all States without distinction. In the introduction of nonindigenous fishes, however, the Bureau responds to applications only with the approval of state authorities. The evil that may result from the indiscriminate planting of new fishes, especially the predaceous species, is obvious, but as it is not generally recognized by applicants that the popular black basses and trouts, for instance, do not dwell together in amity, full precaution is taken to secure requisite information before the fish are supplied.

The extent of government aid to state hatchery work may be judged from the following table, showing the numbers of eggs consigned gratis to state fish commissions during the year ended June 30, 1908:

ALLOTMENTS OF EGGS TO STATE FISH COMMISSIONS, FISCAL YEAR 1908.

State and species.	Number of eggs.	State and species.	Number of eggs.
California: Chinook salmon	68, 647, 550	New York—Continued.	
Colorado:		Lake trout	300, 000
Black-spotted trout	125, 000	Ohio:	
Lake trout	50, 000	Whitefish	[a] 30, 906, 000
Idaho: Brook trout	100, 000	Lake cisco	[a] 2, 070, 000
Illinois: Pike perch	25, 000, 000	Oregon: Chinook salmon	1, 485, 000
Maine:		Pennsylvania:	
Landlocked salmon	100, 000	Whitefish	[b] 76, 860, 000
White perch	700, 000	Lake cisco	10, 720, 000
Maryland:		Silver salmon	100, 000
Rainbow trout	150, 000	Black-spotted trout	126, 000
Yellow perch	2, 080, 000	Lake trout	500, 000
Massachusetts: Rainbow trout	15, 000	Pike perch	[b] 144, 725, 000
Michigan:		Utah: Rainbow trout	50, 000
Landlocked salmon	10, 000	Vermont:	
Lake trout	500, 000	Lake trout	300, 000
Pike perch	43, 000, 000	Brook trout	84, 500
Missouri:		Wisconsin:	
Brook trout	100, 000	Whitefish	15, 000, 000
Grayling	50, 000	Steelhead trout	50, 000
Pike perch	5, 000, 000	Rainbow trout	100, 000
Nevada:		Grayling	50, 000
Lake trout	100, 000	Wyoming:	
Brook trout	200, 000	Steelhead trout	20, 000
New Hampshire:		Black-spotted trout	63, 000
Chinook salmon	100, 000	Lake trout	50, 000
Lake trout	504, 000	Grayling	50, 000
New York:			
Whitefish	15, 000, 000	Total	440, 161, 050
Landlocked salmon	20, 000		

[a] The Ohio Fish Commission cooperated by furnishing a vessel and crew, and defrayed the expenses of collecting these eggs.
[b] The Pennsylvania Fish Commission contributed the cost of collecting these eggs.

In addition to the eggs distributed as above, 3,500,000 yellow perch fry were consigned to Connecticut and 1,475,000 lobster fry to Massachusetts; and

of rainbow trout fingerlings, yearlings, and adults, 44,800 were donated to Maryland and 5,000 to Nebraska.

The oyster-producing States more than any others have asked for the assistance of the Bureau's scientific staff. In Alabama, Florida, Louisiana, Maryland, North Carolina, South Carolina, and Texas extensive surveys have been made or are being made, the oyster grounds charted, biological and physical conditions studied, and the path to successful cultivation pointed out. In North Carolina the declining shad fishery was recently investigated in both its natural history and statistical aspects by the Bureau at the request of the state authorities. State hatcheries have frequently called for aid in the study and treatment of epidemics among the fry and young fish. The results achieved in these various instances will be referred to elsewhere.

International courtesy has prompted the donation of American fish eggs to foreign governments, and the hardiness of such eggs and the facility with which they may be transported out of water for long distances have resulted in the establishment of some of the best of our food and game fishes in distant lands. Thus the brook trout and other American salmonoids are now thriving in Argentina; the brook trout, the rainbow trout, and the black bass are widely distributed in Europe; the rainbow and brook trouts are found in several Japanese lakes; and some of the finest trout fishing in the world is afforded by the rainbow trout in New Zealand, where also the chinook salmon, the blueback salmon, and various other American fishes are now flourishing. During the past year about 4,000,000 eggs of salmons and trouts were shipped abroad. When the Bureau is unable to supply such requests from its own stock, it acts as agent in the purchase from private fish-cultural establishments, supervising the packing and the transportation to the point of embarkation.

PUBLICATIONS.

The 65 large volumes which represent the United States Bureau of Fisheries on library shelves are not the mere routine report or annual statement of funds disbursed and duties discharged. The scientific study and the practical experiment which are the foundation of the Bureau's work yield results of manifold interest and far-reaching significance, and such results are correspondingly fruitful of discussion. The dissemination of the knowledge they afford is, moreover, a recognized function for which the periodical document issue is the established medium. The subject-matter of these volumes is thus coextensive with the scope of the operations of the Bureau—it is biological, fish-cultural, and commercial, treated from standpoints both technical and economic. The names of J. A. Allen, Baird, Bean, Bumpus, Dean, Farlow, Forbes, Gill, Gilbert, Goode, Jordan, Rathbun, Ryder, Verrill, and numbers of other well-known biologists give the publications authority in science; and

the reports of Baird, again, and the pioneers, Atkins, Clark, Green, Hessel, McDonald, and Stone, and their successors, constitute practically a history of fish culture in America. The Manual of Fish Culture, first issued in 1897 and revised in 1900, is yet the only publication in English covering that subject. The seven-volume Fisheries and Fishery Industries of the United States, by Goode and his associates—Clark, Collins, Earll, Elliott, McDonald, and True—though published about twenty years ago, remains a standard work of reference. Of special interest and value during recent years have been the numerous contributions of Evermann, either alone or in collaboration, on the fishes of Hawaii, Porto Rico, the interior and coastal waters of America, etc.; the reports of Benedict, Rathbun, and others on crustacean resources, of Herrick on the lobster, of Kunz on pearls, of Moore on oysters and oyster culture, of Parker and Herrick on the special senses in fishes, and various other papers by regular assistants of the Bureau on economic, biological, and fish-cultural subjects. In addition to the foregoing, the publications treat of the physical conditions in lakes and streams, the methods used in deep-sea investigation, and all forms of minute animal and plant life in their relation to fishes—reaching into the fields of oceanography, hydrography, geology, and chemistry, as well as biology. The Bureau is thus responsible for a literature which no bibliography of natural science could omit and which has an educational value and popular interest widely acknowledged and availed of.

For the first ten years of the existence of the Bureau its publications were comprised in a series of annual octavo volumes known as the "Commissioner's Report." In 1881 another series was begun, likewise of annual issue, and designated "Bulletin of the United States Fish Commission." These two series endured as instituted until the year 1905, when new legislation brought about a change. So far as form is concerned, however, the change affects only the commissioner's report. This report is no longer a bound book containing a detailed discussion of the year's work, with special reports appended, but is reduced to a brief administrative statement of results, occupying less than 50 octavo pages. The special reports formerly published as appendixes and making up the major portion of the original volume are now issued as separate, independent pamphlets under distinct title-pages and covers. These papers are, in general, fish cultural and economic, being detailed accounts of special investigations or experiments briefly noticed in the commissioner's report, and, as a rule, contemporary. The relationship of their subject-matter is recognized in their size and typographical style, which is such as to permit them to be bound, if desired, with the commissioner's report to which they pertain. They are issued at no fixed intervals, but from time to time, according to quantity and character of material and the exigencies of printing, each annual group, however, being usually completed within the year the commissioner's report is issued.

A Penobscot River salmon weir. Large numbers of these traps are set in the Penobscot during the short season, and they intercept practically the entire run of salmon. The fish thus caught are the sole source of eggs for the hatchery on Craig Brook, a small tributary of the Penobscot. (See p. 1399.)

Largest seine in the world. This seine, operated for shad and alewives at Stony Point, Virginia, on the Potomac River, was the longest net of the kind. The net proper was 9,600 feet in length, and the hauling ropes at the ends were 22,400 feet long, giving 32,000 feet as the total sweep of the seine, only one end of which shows in the illustration. The seine was hauled by steam power and the labor of 80 men, and was drawn twice daily, at ebb tide, throughout the season. As many as 3,600 shad were taken at one haul, and 126,000 in one season, and 250,000 alewives were caught at one time. Recently the season's yield of shad fell to 3,000, and the fishery was consequently discontinued in 1905 after having been carried on for a century. This seine was a source of eggs for the Bureau's shad hatchery on this river. (See p. 1399.)

The bulletin remains as heretofore, composed of papers (chiefly technical) upon all phases of aquatic biology studied by the Bureau or its collaborators. The volumes are annual, in royal octavo, with continuous pagination and general index. The separates are issued at irregular intervals, as are the pamphlets just described, and a volume is ordinarily closed within the year following the date in its title.

The publications are distributed gratis to all persons or institutions that desire them. A permanent mailing list is maintained, and individual requests also are complied with as received. The change affecting the contents of the annual report, however, carried with it a new plan in the general distribution of documents. The laws establishing the report and bulletin had contemplated their issue in the form of annual bound volumes only, though it was possible to obtain a small edition of special papers in advance as separates. The separates, of course, offered the advantage of promptness in publication, convenience to the reader interested in a particular subject, and economy to the Bureau where without them it would have been necessary to supply entire volumes to persons desiring only a part. Accordingly, when revision of the printing laws made a new course possible, the pamphlet form was adopted almost exclusively for general distribution, exception being made only in the case of reference libraries, government departments, public fishery organizations, institutions of learning, etc., for whose purposes the annual bound volumes were better suited. To all other addresses on the mailing list and to all subsequent correspondents the Bureau forwarded a circular announcement of the change which was to take effect, furnishing a classification of subject-matter, and asking to be advised what papers would be desired in future. To the extent of the edition provided, any or all of the documents published are now supplied in accordance with the wishes thus ascertained. The subjects covered in the papers may be classified as follows:

1. Annual report of the commissioner.
2. Fish culture:
   - (*a*) Methods.
   - (*b*) Distribution of fish and eggs.
   - (*c*) Fish diseases and parasites.
3. Aquatic biology:
   - (*a*) Economic investigations.
   - (*b*) Explorations and surveys, the methods, apparatus, etc.
   - (*c*) Descriptions of species and faunal lists.
   - (*d*) Morphological, physiological, and pathological studies.
4. Commercial fisheries and related industries.

For convenience of reference all publications of the Bureau are given a serial number, document 645 being the last issued. A list of titles of all available documents, arranged by numbers and indexed by subjects, is kept up to

date and can be had upon request. Most of the earlier numbers are now out of print, some of the most valuable works unfortunately being no longer obtainable from any source unless from secondhand-book dealers. Of some important recent works an edition of 2,000 was exhausted within a year, and several documents of particular public interest have run through eight or ten editions. It is now possible to supply only a few odd back volumes and some 300 different pamphlets.

The permanent mailing list, which is steadily growing, includes at present some 1,500 addresses, representing various national and state government departments, fishery organizations and biological societies, public libraries and museums, colleges, newspapers and magazines, numerous fish culturists, educators, students, sportsmen, and other persons with related interests. It is in the daily requests for particular papers, however, that the public interest in the Bureau's work is most manifest. During the past year, which has shown an especially marked increase in this respect, 25,423 documents were sent out in response to special requests.

As already stated, the Bureau distributes its publications free upon request. The Commissioner's Annual Report and the Bulletin (but not the independent pamphlet reports) can also be obtained free from Members of Congress, each United States Senator and Representative receiving a quota from the edition provided for this purpose. The bulletin in this edition is the cloth-bound volume, delivered annually. All of the documents can be purchased in pamphlet form from the Superintendent of Documents, Government Printing Office, Washington, D. C., at a price representing 10 per cent more than actual cost.

SOME RESULTS OF THE WORK.

FISH CULTURE.

Much evidence can be adduced to show that the fish-cultural operations of the General Government are of direct financial benefit to the country at large. The results in the case of some species have been so striking and so widespread that it would be almost as supererogatory to refer to them as to discuss the utility of agriculture; in the case of other species there can be no doubt of the value of the work, although it may be possible but occasionally to distinguish the effects of human intervention on the fish supply from the effects of natural causes. The outcome of the Bureau's efforts to increase the food supply is naturally most evident in the case of small streams, lakes, and ponds, of which thousands have been successfully stocked with the most desirable food and game species. It is not necessary to refer further to this work, but a few of the important results of operations in public waters may appropriately be mentioned.

The leading river fish of the eastern seaboard is the shad. No other anadromous species has been more extensively cultivated and none is now so

dependent on artificial measures for its perpetuation. Inasmuch as the principal fisheries are in interstate or coastal waters and the movements of the fish from the high seas to our rivers and back to the high seas place it beyond the claim to ownership which might be urged by the various States were the shad a permanent resident within their jurisdiction, it seemed especially desirable and necessary that this species should be fostered by the General Government for the benefit of the entire country. For this reason, and owing to a serious decline that had already set in, the shad was one of the first species whose artificial propagation was taken up by the Bureau, and its cultivation is to-day a leading factor in fishery work, almost every large stream having been the site of hatching operations. The extent of the work may be gauged when it is stated that nearly 3,000 millions of young shad have been planted by the Bureau in coastal streams, and a very significant point is that the eggs from which these fish were hatched were taken from fish that had been caught for market, and hence would have been totally lost if the Bureau had not collected them from the fishermen.

The great multiplication of all kinds of fishing appliances on the coast, in the bays, in the estuaries, and along the courses of the rivers, resulted in the capture of a very large part of the run each season before the shad reached the spawning grounds, and hence the natural increase was seriously curtailed, and, in some streams, almost entirely prevented. Yet the shad catch increased, and for many years the fishery prospered in the face of conditions more unfavorable than confront any other fish of our eastern rivers. At length, however, the unrestricted fishing became greedy to an overwhelming extent. The mouths of the rivers and the lower waters through which the shad must pass became so choked with nets that fishing gear farther upstream could make but slender hauls; and for several years there has been a steady decline in catch, which threatens to result in the extinction of the fishery. The Bureau has continued its efforts of propagation, but these are curtailed by the factor that is also destructive to the fishery. When they first enter the streams the shad are not ripe and are useless to the hatcheries, and the spawntakers must therefore wait for the run farther upstream; but with the recent exhaustive fishing in the salt waters so few fish have escaped that the egg collections have diminished to an alarming extent, being reckoned now in millions where formerly they were hundreds of millions. Under such conditions it is impossible to propagate enough fish to offset the quantities taken, and the shad fishery is fast being deprived of its one support; while the present meager shad catch together with the enforced curtailment of propagation speaks even more convincingly of the value of artificial measures than did the preceding increase.

The long continuance of the Penobscot as a salmon stream for many years after all other New England rivers had ceased to carry this fish is directly attributable to the work of the Bureau on that stream. So dependent on

artificial measures has been the perpetuation of the salmon supply that it is believed the obliteration of the run and the wiping out of a long-established fishery would ensue within five years after the suspension of fish-cultural operations. Physical conditions in the Penobscot have become so unfavorable for the passage of salmon to the spawning grounds that natural reproduction is now almost if not altogether inhibited; and the only noteworthy source of young salmon is the eggs obtained by the Bureau from salmon purchased from the fishermen.

Evidence is not lacking to show that the long-continued and increasingly extensive fish-cultural operations on the Great Lakes have prevented the depletion of those waters in the face of the most exhausting lake fisheries in the world. The luscious whitefish, the splendid lake trout, the excellent pike perch, or wall-eyed pike, may be hatched in such numbers as to assure their preservation without serious curtailment of the fisheries. The absence of concerted protective measures, however, on the part of the various States interested has the tendency to minimize the effects of cultivation and would seem to justify, if not imperatively demand, the assumption of jurisdiction by the Federal Government.

The magnitude of the salmon fisheries of the Pacific States has required very extensive artificial measures to keep up the supply. The operations of the Bureau, in combination with those of the States, have been gradually extended in both scale and scope until they have now attained a tremendous extent and are addressed to all the species whose cultivation is as yet demanded. The quantity of Pacific salmon eggs collected by the Bureau in 1908 was over 200,000,000, equivalent to 1,700 bushels.

A remarkable fact in the history of the Pacific salmons—of which there are five species—is that without exception all fish which enter any stream on the entire coast die after once spawning, none surviving to return to the sea. This wise provision of nature to prevent the overstocking of streams has been made foolish by the appearance of man on the scene; he not only catches the salmon in the coast waters and the lower courses of the rivers with gill nets, seines, and pound nets, in the upper waters with the same appliances supplemented by the fish wheels, and on the spawning grounds with all sorts of contrivances, but in certain sections even carries his foolhardy greed to the extent of barricading the streams so that no fish can reach the waters where their eggs must be deposited. Natural reproduction, thus so seriously curtailed, is not sufficient to keep up the supply in many of the streams where fishing is most active, for many of the eggs escape fertilization, many more are eaten by the swarms of predaceous fishes that haunt the spawning beds, and many are lost in various other ways during the long hatching period; while the helpless fry and alevin fall a ready prey to the same fishes in the upper waters and the young salmon have to run

Catching and sorting the brood fish at a trout-cultural station in the Rocky Mountains. (See p. 1402.)

Stripping and fertilizing trout eggs at a station in the Rocky Mountains.

the long gauntlet of the rivers only to meet new foes in the estuaries, on the coast, and in the open sea.

It is, therefore, no wonder that artificial propagation on a large scale is imperatively demanded in the western salmon streams, and is actively urged and highly commended by fishermen, canners, business men, and the public at large. The beneficial influence of the work of the Government, supplemented by that of the three coast States, has been unmistakable in some sections and can not be doubted in general; but it is of course very difficult to distinguish definitely the increase due to natural from that due to artificial propagation. The history of the salmon fishery in the Sacramento River in California, and the recent increase in the catch notwithstanding most unfavorable physical conditions in that stream, afford unmistakable evidence of the value of cultivation. Some very suggestive though not altogether conclusive information relative to the benefits of salmon culture in the Columbia River has been furnished by marking young salmon before releasing them from the hatcheries. The number of marked salmon that returned as mature fish and were captured and reported indicates a very large percentage of survivals and suggests the growing dependence on artificial propagation for the maintenance of the runs.

In the case of marine hatching operations it is so difficult to prove beneficial results that their utility is doubted by some people. When the Bureau began the cultivation of the cod and the lobster many years ago, it proceeded on the principle that the effects of the fishermen's improvidence could be counteracted by artificial propagation. The ultimate success of cod and lobster culture on the Atlantic coast was therefore confidently expected, and the expectations have been more than realized. Practical results of an unmistakable character were first manifested nearly twenty years ago, since which time a very lucrative shore cod fishery has been kept up on grounds that were entirely depleted or that had never contained cod in noteworthy numbers in the memory of the oldest inhabitants. There is much unsolicited testimony on this point from many people who have profited from the operations of the Maine and Massachusetts stations. The benefits have not been confined to the immediate vicinity of the hatcheries, but have extended westward and southward along the Middle Atlantic coast and eastward along the whole coast of Maine. The benefits of lobster culture have been slower in appearing, owing, in part at least, to the less extensive operations and the excessive mortality to which the young are liable; but from all parts of the New England coast there are being received reports of more lobsters, particularly of small size, than have been seen for many years, and there is reason to believe that the long-continued decline of the lobster fishery has been arrested.

ACCLIMATIZATION.

Economic results of great value have come from the transplanting of native aquatic animals into waters in which they are not indigenous and from the introduction of fishes of foreign countries into the United States. The supply of food and game fishes of every section of the country has thus been increased and enriched, fisheries of vast extent have been established, and the pleasures of angling have been greatly enhanced.

In all the waters of the eastern, central, and southern parts of the United States the range of every important native food and game fish has been extended artificially. Especially extensive work has been done with the black basses (*Micropterus*), the crappies (*Pomoxis*), the rock bass (*Ambloplites*), the sunfishes (*Lepomis*), the brook trout (*Salvelinus fontinalis*), the lake trout (*Cristivomer namaycush*), the landlocked salmon (*Salmo sebago*), and the catfishes (*Ameiurus* and *Ictalurus*). Among the more conspicuous examples of this class of work has been the stocking of the Potomac River with black basses, crappies, and catfishes.

Among the eastern fresh-water fishes that have been established and more or less widely colonized in the Rocky Mountains or in transmontane regions are the large-mouth black bass, the crappy, the yellow perch, several catfishes and sunfishes, and the brook trout. Sportsmen of all the Western States can now find excellent black-bass and brook-trout fishing. Colorado, which has known the brook trout only a few years, is thoroughly stocked and affords unsurpassed opportunities for anglers. So successful has been the work in that State that the Government now draws most of its supply of brook-trout eggs therefrom, and the progeny of Colorado fish are used for replenishing eastern waters from which the original stock was taken for introduction into Colorado.

The most noteworthy results of the introduction of native fishes into new regions have been seen in the Pacific States and represent two contributions from the Atlantic seaboard—the shad and the striped bass. The economic outcome of the acclimatization of these fishes is without parallel in the entire history of migratory species.

The colonizing of the shad on the Pacific coast was one of the greatest achievements in fish acclimatization. Aside from the important financial results, the experiment was noteworthy because of certain changes that have occurred in the habits of the species, and because the feat of transporting shad fry across the continent at that early day was justly regarded as remarkable, and had a marked influence on the development of fish transportation, which has now attained such perfection. With the experiment were associated two of the pioneer fish culturists of America, whose name and fame are known the world over—Seth Green and Livingston Stone. Relatively small plants of

shad fry were made in the Sacramento River, California, in 1871, 1873, 1876, 1877, 1878, and 1880, and in the Columbia River, between Oregon and Washington, in 1885 and 1886, the aggregate for each stream being less than one million and only one hundredth of the plants sometimes made in an east-coast river in a single season.

In April, 1873, the first shad was taken in California, and shortly thereafter many more were caught in the vicinity of San Francisco; by 1879 the fish had become numerous, and by 1886 it had become one of the most abundant food fishes of the State. In 1876 or 1877 shad were first taken in the Columbia, so it is evident that an offshoot from the California colony soon migrated northward and had already established itself when the new emigrants arrived from the East eight or nine years later. By 1881 the fish seems to have become distributed along the coast of Washington, and in 1882 reached Puget Sound. It was nine years later, however, when the first pioneer was recorded from Fraser River, British Columbia, and the same year there was a report of shad in Stikine River, southeast Alaska. In 1904 a fine roe shad, caught at Kasilof, on Cook Inlet, was the first known arrival in that remote region. To the southward the fish is found as far as Los Angeles County, and the present range of the species thus extends along about 4,000 miles of coast. It is not improbable that the migrations of the shad will extend still farther.

The two great centers of the shad's abundance are the Sacramento basin and the lower Columbia River, and it has been asserted that in either of these waters more shad could be taken than in any other water course in the country. The catch affords an inadequate criterion of the shad's abundance, for fishermen and dealers report that it would be easily possible, should the demand warrant it, to treble or quadruple the present yield, as most of the fish are now taken incidentally in apparatus set primarily for other species. Viewed from the purely business standpoint, the transplanting of shad to the Pacific coast has been a remarkably good investment. From the best information obtainable, the entire cost of the experiment was less than $4,000, while the aggregate catch for market in California, Oregon, and Washington to the end of 1907 was approximately 15,000,000 pounds, for which the fishermen received $330,000.

The history of the introduction of the striped bass on the western seaboard is quite similar to that of the shad, and the result has been equally striking. In 1879, 135 young striped bass from New Jersey were deposited in San Francisco Bay, and in 1882 a plant of 300 small fish from the same State was made in the same place. These meager colonies found the waters of California fully as congenial as did the shad, and the fish has shown an almost uninterrupted increase in abundance to the present time. From the San Francisco region the species has gradually spread up and down the coast, and its range may eventually equal that of the shad. Up to 1896 the fish had not been reported outside of

California, but several years thereafter it began to run in some of the coast rivers of Oregon, and in the fall of 1906 half a dozen fine specimens were caught in traps at the mouth of the Columbia River, the first recorded from that stream.

The striped bass, far removed from its ancestral home, has maintained the enviable reputation it enjoys in the East, and is freely recognized by its new friends as one of the best food and game fishes of the Pacific coast. A number of years ago the catch in California exceeded that of any other State, while now it surpasses that of any group of States along the eastern seaboard. The fish has become a prime favorite with anglers, and it is now probably the leading game fish of California. While it always commands a high price in the East, and is often to be ranked as a luxury, its abundance in California waters has so reduced the cost to consumers that even the most frugal can afford to eat it, and a comparison made some years ago showed that throughout the year the San Francisco dealers were underselling the New York dealers by many points. The economic importance of the introduction of the striped bass on the Pacific coast may be judged from the fact that the entire cost of transplanting was less than $1,000, while the value of the catch to the end of 1907 was about $925,000, a sum representing a yield of more than 16,500,000 pounds.

The only fishes which the Western States have given to the remainder of the country are two trouts; but the transplanting of several other trouts is now in progress, and systematic and extensive efforts are being made to establish several of the Pacific salmons in the New England rivers. The foremost contribution of the West to the East is the rainbow trout. The transplanting of this species in regions east of the Rocky Mountains has been a conspicuous success and has proved a decided boon to many communities. Its acclimatization by the General Government was first undertaken in 1880, although it is probable that some years prior thereto small plants had been made in new waters by state commissions or private persons. It has now been introduced into nearly every State and Territory, and has become one of the most generally known fishes in every part of the country. In Michigan, Missouri, Arkansas, Nebraska, Colorado, Nevada, and throughout the Allegheny Mountain region its transplanting has been followed by especially noteworthy results. Its position in the streams and lakes of the Eastern States is that of a substitute and not a rival of the brook trout. It is well adapted for the stocking of waters formerly inhabited by the brook trout, in which the latter no longer thrives on account of changed physical conditions; it is also suited to warmer, deeper, and more sluggish waters than the brook trout finds congenial.

The anadromous steelhead trout of the Pacific coast has been established in Lake Superior and other parts of the Great Lakes as a result of plants of young fish made in 1896, and has also obtained a firm hold in a number of New England lakes, proving a very acceptable addition to the supply of food and

Salmon hatchery at Baird, Cal., the pioneer salmon hatchery on the Pacific coast, located on the McCloud River, a swift stream formed by the melting snow on Mount Shasta. The station can accommodate 25 million eggs at one time, and in 1907–8 produced about 5 million young chinook or quinnat salmon and 10 million eyed eggs. Operations of this hatchery and its auxiliaries at Battle Creek and Mill Creek (73½ million eggs of the chinook salmon were taken in 1907–8) have been the prime factor in maintaining the salmon run in the Sacramento River. (See p. 1400.)

game fishes. It readily adapts itself to a strictly fresh-water existence, and soon reproduces in its new habitat.

The debt that sportsmen owe to the fishery service of the United States and the several States for their acclimatization work is heavy and increasing yearly, and the obligation is shared indirectly, but not the less actually, by hotel keepers, boatmen, merchants, landowners, and others. There could be cited numerous concrete examples of the varied benefits that have come to communities through the stocking of local waters with nonindigenous species. In some cases the improvement in the fishing has so increased the influx of people that land about the waters has increased several hundred per cent in value in a few years.

Quite a number of Old World fishes have been introduced into American waters, and some of them have become well known in various parts of the country. Two European trouts, the brown trout and the Scotch lake trout, have been cultivated here for a score of years, and are now found in many private waters. The acclimatization of the European sea trout and the Swiss lake trout has also been effected. None of these fishes, however, has any superiority over native species, and the demand for them is decreasing. The Asiatic goldfish and the European golden ide or orf and tench are now very familiar ornamental species in America, but have little commercial value; the tench, however, is found in a few streams and reaches the markets in small numbers. Of all the exotic fishes, none is so well known, so widely distributed, so abundant, and so valuable as the carp, which was introduced from Germany upward of thirty years ago. This fish has excited a great deal of criticism, mostly unfriendly, and it is to-day regarded with disfavor by many people, chiefly anglers, because of real or supposed habits that are reprehensible. As a commercial proposition, the bringing of the carp to America has been of immense benefit, for to-day it is one of the common food fishes of the country, it is regularly exposed for sale in every large city and innumerable small towns, it supports special fisheries in 15 States, and it is regularly taken for market in 35 States. The sales at this time amount to fully 20,000,000 pounds annually, for which the fishermen receive $500,000.

The principal carp fishery is in Illinois, where fishermen have for years been reaping a golden harvest, finding a ready sale in the West and also sending large consignments to New York in special cars. The next important center is the western end of Lake Erie, in Ohio and Michigan, where large special ponds have been constructed and a peculiar form of cultivation has sprung up. Other important carp States are Colorado, Delaware, Iowa, Minnesota, Missouri, New Jersey, New York, Tennessee, Utah, and Wisconsin.

It is not as a great market fish, however, that the carp is destined to attain its highest importance among us, but as a fish for private culture and home consumption. The number of farmers and small landowners who are alive to

the benefits of private fish ponds is increasing at a very rapid rate, and hundreds of thousands of such in all parts of the country, but particularly in the great central region, will find in the carp a fish well adapted to their needs and conditions.

It is probable that the commercial value of carp is insignificant compared with its importance as a food for other fishes. It is extensively eaten by many of our most highly esteemed food fishes and is the chief pabulum of some of them in some places. In a number of the best black bass streams, like the Potomac and the Illinois, the carp is very abundant and is a favorite food of the young and adult bass, while in California the introduced striped bass has from the outset subsisted largely on carp and may owe its remarkable increase to the presence of this food.

The consumption of carp is certainly destined to increase greatly; but even if the catch reaches no higher point the introduction of the carp into the United States will remain the leading achievement in fish acclimatization in recent times, and, with the exception of the original introduction of the same fish into Europe from Asia, the most important the world has known.

Among the acclimatization experiments that have not yet been proved successful, but that there is every reason to believe will eventually become so, is the transplanting of the lobster (*Homarus americanus*) to the Pacific coast. There is probably no food animal of the eastern seaboard whose acclimatization on the Pacific coast would prove so great a boon as the lobster. As early as 1873 the Bureau made its first move to supply the deficiency, and up to 1889 five attempts to establish the species were made, the deposits being at various points from Monterey Bay to Puget Sound. No positive results having appeared, the experiment was renewed in the fall of 1906, when a special carload of brood lobsters, numbering more than all the previous plants combined, was dispatched to Puget Sound, and in 1907 a still more extensive plant, aggregating about 1,000 adult lobsters, was made in the same water. Further consignments will be made until the lobster is removed from the list of failures and recorded as a great financial as well as gastronomic success.

BIOLOGICAL INVESTIGATIONS AND EXPERIMENTS.

The long-continued and systematic field and laboratory work of the Bureau has resulted in a most thorough knowledge of the distribution, variation, abundance, habits, etc., of the fishes and other creatures of the interior, coastwise, and offshore waters of the United States, Hawaii, and Porto Rico—a knowledge which is indispensable to the Government in its fish-culture work and to the various States and insular authorities in their legislative efforts to preserve their fishery resources. The practical results of this work are apparent in numerous specific instances.

For a number of years the Bureau has been engaged in an endeavor to develop a practical method of fattening oysters. It is the custom of many oyster growers to transplant their oysters shortly before putting them on the market, to beds where the natural supply of food is luxuriant, and oysters fatten rapidly. In many localities such favorable places are few or entirely lacking, and the oystermen are compelled to put inferior stock upon the market, and thus forfeit the full measure of profit. The experiments that have been carried on are intended to develop a method of producing these fattening beds artifically in localities where they do not naturally exist. By the use of commercial fertilizers it has been found possible to produce the desired abundance of oyster food, and the only important problem yet awaiting solution is that of materially increasing the output of the artificial claire employed for the experiments. Considerable progress toward this end has been made recently, the yield of the claire in 1907 being 176 barrels, against 125 barrels in the preceding year; and as with a given equipment the expenses of operation are not materially increased whatever the product, this increase, if it can be carried further, as present conditions indicate, will result in sufficient margin between the cost of the treatment and the increased value of the fattened oysters to warrant its recommendation as a commercial process. The oysters fattened by this method are as fine as any placed on the market, and have been used with satisfaction at some of the best hotels and clubs of New York, Philadelphia, and Washington.

Upon two subjects in particular has the Bureau expended much energy and at last achieved results by persistently sounding the note of warning. The utmost efforts in artificial propagation can not save the shad fishery without the aid of laws to permit a certain number of spawning fish to reach the streams; while on the other hand no practicable protective laws can save the oyster supply without cultural work to keep up the beds. The Bureau has no power to do more than hatch fish in the one case, devise methods of culture in the other, and cry out the needs of both; and it lies solely with the States to provide for the needs.

North Carolina rose to the emergency of the shad situation a few years ago and asked the aid of the Bureau in determining the actual protection required by the shad, the actual condition of the fishery, and the possible remedies for a rapidly diminishing yield. The Bureau's recommendations were asked for by the state legislature, and a commission was appointed to draft salutary laws, which have since gone into effect, confining gear to prescribed areas and leaving clear channels for the passage of the fish. Immediate result was seen at the government hatchery in the Albemarle region. The collection of shad eggs in these waters in five years had dropped from seventy-five millions to six and one-half millions. The next year, which was the first of enforcement of the new laws, the collection was twenty-five and one-half millions, and in 1908 the most

successful shad hatchery was in this State, the egg collections exceeding fifty-five millions.

The oyster fishery has had a common history in all of the Southern States, of which Maryland, once the foremost in oyster production and the last to resort to systematic cultural measures, affords the most notable example. The laws controlling the fishery in Chesapeake Bay have been designed to protect the natural beds, but have not encouraged or protected the oyster planter, and the natural beds, thus practically the sole reliance, in time failed to sustain the tremendous draft upon them. Between 1880 and 1897 the product fell 31.6 per cent; in 1904 it was 39 per cent less than in 1897.

The Bureau had for many years pointed out the short-sighted policy that was resulting in the steady decline of the oyster industry, and was at length gratified to find that the State had taken heed of the warning and enacted a comprehensive law favoring oyster planting. The work that has now been undertaken by the Maryland Shell Fish Commission to remedy the alarming condition of the oyster grounds will be the most complete and accurate of its kind. It consists of the survey and delimitation, by the aid of the United States Coast and Geodetic Survey and the Bureau of Fisheries, of all natural oyster beds in Maryland waters, to be marked and set aside as public fishing grounds, operated under the existing protective laws. All other suitable grounds will then be reserved by the State to be leased to oyster planters, whose enterprise will be encouraged and their rights protected as was not possible heretofore.

Up to 1898 there were few planted beds of oysters in Louisiana waters. Investigation of the oyster grounds by the Bureau in that year, however, led to the passage of beneficial laws and proved a general stimulus to oyster culture in that State, as is shown by the fact that some 20,000 acres of bottom were soon under cultivation. In 1906 the State Oyster Commission, still further to promote the local industry, again asked the Bureau's assistance, and large areas of unutilized bottom were examined to determine their productive capacity. The conditions were found to be exceptionally favorable, and experimental plants produced 3½ to 4 inch oysters in quantities of 1,000 to 2,000 bushels per acre, within two years after the cultch was put down. In Barataria Bay, where there had been no oysters whatever, such promising beds were established that several hundred acres of adjacent bottom were immediately leased by prospective planters. Other localities, though they have so far shown no such conspicuous commercial enterprise, may be expected to prove equally productive.

Experiments in sponge culture have been in progress for several years, and have now developed a practical system by which sponges may be produced from cuttings at a cost much less than that entailed in taking them from the natural beds. In view of the more rapid depletion of the natural beds which

Fisheries steamer Fish Hawk, engaged in hydrographic and biological surveys on the New England coast, and often employed as a shad hatchery on east-coast rivers. (See p. 1385.)

Main deck of steamer Fish Hawk, showing arrangement of McDonald automatic jars for hatching shad.

will undoubtedly result from recent changes in the methods of the fishery, the Bureau is convinced that the preservation of the American sponge industry will depend upon cultivation; and as it is estimated that about $1,500,000 worth of sponges were taken in Florida during the past year, the failure of the fishery would be a serious commercial loss to the State.

In cooperation with the Rhode Island Fish Commission, the Bureau has developed new methods of lobster and soft-shell clam culture which are being applied with success in New England. Experiments with the hard-shell clam are now in progress at Beaufort.

Important work recently undertaken is an effort to establish mussel culture in the Mississippi Valley. The supply of mussels in those waters, on which is based a pearl-button industry valued at about $5,000,000 per annum, with an investment of $6,000,000, is being rapidly exhausted, and the mussel fishermen and manufacturers recognize that without scientific cooperation of the Government the business is doomed to early extinction. The Bureau in one season's work has practically, though not conclusively, shown a method by which the pearl mussels can be propagated, and is demonstrating that the work can be carried on at a comparatively small expense in connection with the already established operations in rescuing fishes from the overflowed lands, the fishes reclaimed being employed, without injury to themselves, in the dissemination of the larvæ of the mussels. There have been liberated 25,000 fish, bearing about 25,000,000 young mussels ready to drop and begin their independent existence, and already past the stage when they are most subject to fatality. The work is also capable of application to waters under private control and will probably become a source of respectable revenue to farmers and others whose property embraces streams, ponds, and lakes. The importance of this work is urgently insisted upon by the National Pearl Button Manufacturers' Association, which embraces practically the entire capital invested in the business.

In the field of fish diseases great progress has been made in the extension of knowledge of the causes of many of the fatalities which sometimes make a clean sweep of the hatcheries and which heretofore could not be adequately coped with because their etiology was not understood. The services of the scientific staff in this regard have been not only of great benefit to the Government, but are highly regarded and frequently availed of by state and private fish-culturists. Among the direct material aids rendered to fish culture in the past four or five years are the following: (1) Determination of the cause and remedy for the fatal malady known as the "gas disease," which at one station killed 1,200,000 brook-trout fry out of 1,300,000 on hand; (2) isolation of a bacterial organism producing a fatal disease in trout, and discovery of a possible remedy; (3) determination of the cause of a fatal protozoan disease in trout:

(4) discovery of a remedy for the diatom disease of lobster eggs and larvæ; (5) studies of the causes of death of fish in captivity and the determination in a number of cases of the responsible peculiarities in the water supply; (6) studies of the character of streams and the effects of various conditions on fishes, which studies have supplied much information on the subject to the public; (7) determination of the effects on fishes of galvanized iron and other metallic containers used in transportation of fish and fry, and indication of certain undesirable types of containers.

COMMERCIAL FISHERIES.

The importance to the fishing interests of the work of the Bureau in connection with the economic fisheries is widely appreciated and freely acknowledged. The statistical inquiries of the Bureau afford the only adequate basis for determining the condition and trend of the fisheries and the results of legislation, protection, and cultivation. Among the numerous special matters in which the Bureau has benefited the fisheries the following may be mentioned:

By bringing to the attention of American fishermen new methods and new apparatus, new fisheries have sometimes been established and new fields exploited.

By the introduction of gill nets with glass-ball floats for taking cod the winter cod fishery of New England was revolutionized. In a single season, shortly after the use of such nets began, a few Cape Ann (Gloucester) fishermen took by this means over 8,000,000 pounds of large-sized fish, and as much as $50,000 has sometimes been saved annually in the single item of bait.

By the dissemination of information regarding new fishing grounds important fisheries have been inaugurated. Thus when the abundance of halibut off the coast of Iceland was made known by the Bureau a fishery was begun which yielded from $70,000 to $100,000 annually to the New England fishermen.

The Bureau has experimented with various unused or little-used products in order to determine their economic value and to suggest the best ways of utilizing them. Less than fifteen years ago there was practically no market for the silver hake or whiting (*Merluccius bilinearis*), and immense quantities incidentally taken in pound nets and other apparatus were thrown away. The Bureau pointed out the possibility of preparing a marketable salt whiting; and it is a significant fact that in a few years the sales of this fish in New England have increased from about 100,000 pounds to 5,000,000 pounds.

Owing to the appalling mortality among the crews of the New England fishing vessels, due in large part to the foundering of the vessels at sea, the Bureau many years ago undertook the introduction into the offshore fisheries of a type of craft which would combine large carrying capacity and great speed

with enhanced safety. By correspondence, discussions in the daily press, personal interviews, exhibition of models, and finally by the actual construction of a full-sized schooner (the *Grampus*) with the requisite qualities, the Bureau was able to inaugurate a momentous change in the architecture of fishing vessels, so that for a long time the New England schooners have been constructed on the new lines, with a constant minimizing of disasters and a decided increase in efficiency. For other fisheries and regions the Bureau has likewise advocated improved types of vessels and boats especially adapted to local conditions, and has published plans and specifications embodying the results of studies of the fishing flotilla of the world. The results of the Bureau's efforts in this line, in saving life and property, in increasing the usefulness of the vessels, and in improving the quality of the catch as landed can not be estimated, but the beneficial effects may be partly appreciated when it is stated that during the ten years ended in 1883, when the old types of vessels were in use, there were lost by foundering, from the port of Gloucester alone, 82 vessels, valued at more than $400,000, with their crews of 895 men; while during the ten years ending in 1907 the losses from this cause aggregated only a fourth as many vessels and men.

Fishery schooner Grampus, built by the United States Government as an object lesson. The general adoption of this type of swift, safe vessel in the offshore fisheries has resulted in great saving of life and property, and has otherwise promoted the fisheries.

The fresh-fish fleet at T wharf, Boston. Larger quantities of fresh sea fish are landed at Boston than at any other port in the United States. The principal species are cod, cusk, haddock, hake, pollock, halibut, swordfish, and mackerel, together with lobsters, oysters, and clams. A day's receipts of fresh fish from the grounds off the New England coast have sometimes exceeded 2,000,000 pounds.

GENERAL INDEX.

[Part 1 includes pages 1–696; part 2, pages 697–1412.]

Page.

Abnormal gas content of water 898–905
Acclimatization 947–989, 1402–1406
  American fishes, Argentina 955–966
    Austria 977–990
    Italy 947 954
    New Zealand 967–976
  black bass, Austria 982
    Italy 947–954
  brook trout. *See* trout.
  carp, United States 1405–1406
  catfish, New Zealand 970, 973
  European trouts, United States 1405
  lobster, Pacific coast 1406
  rainbow trout. *See* trout.
  salmons, Argentina 955–966
    New Zealand 967–976
  shad, Pacific coast 1402–1403
  steelhead trout, eastern states 1404
  striped bass, Pacific coast 1403–1404
  sunfish, Italy 947–954
  trout, Argentina 955–966
    Austria 977–990
    Colorado 691–692, 1402
    eastern states 1404
    Italy 947–954
    New Zealand 967–976
  whitefish, New Zealand 970, 973
Adee, Alvey A., remarks 17
Adriatic Sea, sponge fisheries 477–478
Ægean Sea and Asia Minor, sponge fisheries 478–479, 513–543
Aeration apparatus for fish culture 716–717, 1033–1034
Aeration, remedy for fish disease 891–932, 937–940
Alabama, delegates 7
Alaska, delegates 7
  salmon-inspection service 1392–1393
Alaska Packers Association, complimentary luncheon 60
Albatross, United States Fisheries steamer 1384
Aldrich and Company, Robert, on effects of gunfire on fishes 29
Algæ in fish-cultural waters, destruction 871–890
Algeria, sponge fisheries 484, 534
American Fisheries Society, award offered by 69
  complimentary luncheon 36
  delegates 10
American fishes abroad 955–966
  See also Acclimatization.
American Microscopical Society, delegate 10
American Museum of Natural History, award offered by 69
  reception 65
American societies, delegates 10–11
American states and territories, delegates 7–10

Page.

Anatomy of ear of squeteague 1211–1224
Angling 60, 61–62, 187–208
  California and Florida 199–207
  exhibit of fishes and fishing tackle 1311–1314
  legislation 187–198
  national aspects 193–198
  privileges in private waters 60, 61–62
Anglo-Belgian fishery declaration 167
Anglo-Denmark fishery convention 121, 169
Anglo-French fishery conventions 97, 113, 151, 158
Antarctic seals and seal fisheries 317–319
Anthony, R., culture of turbot 859–870
Antipa, Dr. Gregoire, named as vice-president 25
Appalachian forest reserve advocated 67
Apparatus, fish culture 697–757, 767–779, 799–810, 991–1040
  oyster culture 1299–1301
  photography, subaquatic 1122–1125
  radiographing pearl oysters 308–312
  See also Fish culture, appliances.
Aquarium, cleaning devices 1032–1033
  fungus disease on fishes 929–940
  New York, reception to delegates 65
    treatment of fungus 929–932
Aquatic mammals, protection 148–150
Aquiculture, new principle 759–780, 866–869
  See also Fish culture.
Aquino, Radler de, named as vice-president 24
  international fishery dictionary 49
Argentina, American fishes acclimatized 955–966
Artificial nests for bass 720–721, 993
Asia Minor and Ægean Sea, sponge fisheries 478–479, 513–543
Atkins, Charles G., award received 72
  foods for salmonoids 839–851
  sea mussels and dogfish as food 252
Atlantic Ocean, sponges 493–494
Atlantic salmon, culture 718–719, 1399–1400
  parasites 1153–1173
Australia, sponge fisheries 492
Austria, American fishes acclimatized 977–982, 983–990
  delegate 6
Austrian Fisheries Society, delegate 6
Awards, committee on 25–26, 68, 71
  conditions governing 70
  conferred, list of recipients 71–72
  offered, list 69
Ayson, L. F., American fishes in New Zealand 967–976
Azygia sebago, a new trematode parasite 1176–1184

Bahama Islands, sponge fisheries 470–473
Barricades in salmon streams, designs 726–732
Bass, black, acclimatization 947–954, 982
  nests, artificial 720–721, 993

Page.

Bass, protection ... 185
  striped, culture ... 706–707
Bayer, H. von, fishways ... 1041–1058
  measuring fish eggs ... 1009–1014
Beam-trawl fishing ... 88–89
Bean, T. H., remarks on anglers' rights ... 62
  toadfish ... 1069
  whitefish regulations ... 688
Belgian "devil" ... 85, 99
Bengoechea, Ramon, named as vice-president ... 25
Bermuda Natural History Society, delegates ... 7
Besana, Giuseppe, American fishes in Italy ... 947–954
Bigelow, H., award offered ... 70
Biological investigations, United States Government ... 1383–1385, 1406–1410
  laboratories, United States Government ... 1384
Birds of Peru, guano-producing ... 358–362
Birge, E. A., gases in Wisconsin lakes ... 1273–1293
Black bass, acclimatization ... 947–954, 982
  artificial nests ... 720–721, 993
  protection ... 185
Blood of fishes, effects of changes in water density ... 1143–1150
Boardman, W. H., lobster question ... 214
Boats, fishing, Peru ... 341–345
Borodine, Nicholas, message ... 46
  international fishery dictionary ... 47–48
  proposal for international fishery dictionary ... 41, 49
Boston Fish Bureau, courtesies extended ... 66
Boston, visit to ... 66
Boundary waters, fisheries regulations ... 85, 181–186
Bower, Seymour, whitefish regulations ... 691
Bowers, George M., award offered ... 70
  congress opened ... 18
Blue Ridge Rod and Gun Club, complimentary luncheon ... 41
Brazil, delegate ... 6
Breeding habits of horned dace ... 1125–1136
  kelpfish ... 1140–1141
  toadfish ... 1077–1087
Brook trout:
  acclimatized in Argentina ... 955–966
    Austria ... 981, 983–989
    Colorado ... 691–692, 1402
    Italy ... 947–954
    New Zealand ... 971
  culture ... 712–718
  disease ... 941–946
Brooklyn Institute of Arts and Sciences, Museum, award offered by ... 69
Bumpus, H. C., award offered by ... 70
  named as president ... 22
  lobster question ... 213, 214
Bureau of Fisheries, United States. *See* United States Bureau of Fisheries.

Cail fishway ... 1049, 1052–1057
California, delegates ... 7
  game fish and fishing ... 201–205
Canada, angling ... 62
  delegate ... 6
Canada-United States fisheries commission ... 85–87, 181–186
Canal Zone, delegates ... 7

Page.

Carbo, Esteban F., fisheries of Ecuador ... 52–54
Carnegie Institution of Washington, delegate ... 11
Carp, acclimatized in America ... 1405–1406
  fishery in United States ... 1405–1406
  value in United States ... 1404–1406
Chars, acclimatization ... 947–990
  culture in United States ... 712–718
  See also Acclimatization, trout *and* Trout.
Cheyney, John K., award offered by ... 70
China, delegates ... 6
  fisheries ... 367–373
Clark, Frank N., whitefish production of Great Lakes ... 635–642
  whitefish regulations ... 688, 692–693
Cleaning device, hatching troughs ... 1030–1031
  ponds and aquaria ... 1032
Cod culture, method and results in Norway ... 799–816
  United States ... 736–737, 1401
Coker, Robert E., named as vice-president ... 25
  fisheries and guano industry of Peru ... 333–365
Collection of fishes from overflowed lands ... 724
Collecting tub ... 995
Colombia sponge fisheries ... 475
Colorado, brook trout acclimatized ... 1402
  delegates ... 7
  trout culture ... 713–714
Columbia River salmon fisheries, preservation ... 186
Commercial fisheries, United States ... 1385–1393, 1410–1411
Committees:
  awards ... 25–26, 68, 71
    report ... 71
  organization ... 4
  programme ... 27
  resolutions ... 26, 63
Competitive awards ... 69–72
Congress, International Fishery, appeal to ... 542–543
  awards ... 25–26, 68, 71–72
  elections of officers ... 14
  members ... 5–13, 14
  minutes ... 15
  object ... 14
  officers ... 3–4
  organization ... 1–15
  papers and discussions ... 77–1412
  permanent commission ... 35, 41, 73
  publications ... 15
  regulations ... 14–15
  resolutions ... 14, 67, 68
  resources ... 15
  sessional business ... 17–76
  views adopted ... 67
Connecticut, delegates ... 7
Conservation of natural resources, resolution ... 67
  remarks by Gifford Pinchot ... 57–59
Cooper, Alexander, remarks on menhaden fishing ... 278
"Coopers" ... 81, 98
Copper plating fish casts ... 1362–1363
Copper sulphate, algæ destroyer ... 871–890
Costia necatrix, prevention ... 917–928
Cotte, Jules, sponge culture ... 587–613
Counting fish eggs ... 739–741, 1009–1014
  young fish ... 741, 1001–1004
Cuba, sponge fisheries ... 472–474
Curtis, W. C., culture of fresh-water mussels ... 615–626

Page.
Dace, horned, breeding habits 1125–1136
Dannevig, G. M., marine fish hatchery in Norway . 799–809
utility of sea-fish hatching 811–816
Debate in International Fishery Congress, rules. . . . 15
Delaware, delegates 7
Delegates, list . . . 5–11
Dennis, Oregon Milton, fish protective legislation . 187–192
Density of water, Woods Hole region 1240
effect of changes upon fishes 1143–1150
Department of State, United States, meeting at 17
Departments of United States Government, delegates 5–6
Designs for fishways . . 1045–1057
Devices for fish culturists 739–741, 991–1040
See also Fish culture, appliances.
"Devil" in North Sea fisheries 85, 99
Dictionary, international fishery 41, 47–49, 64
Dioxide of hydrogen, remedy for fungus 929–932
Discussions:
acclimatization of fishes in New Zealand 974
effects of menhaden fishing 277–278
gaseous changes in lake waters 1293–1294
international fishery regulations 83–90, 179
lobsters and lobster problem 213–217
plea for observation of habits of fishes 1068–1069
Rhine salmon 829
sea mussels and dogfish as food 249–257
whitefish production of Great Lakes 685–695
Disease of fishes 907–946, 1409
See also Fish diseases.
Disease of sponge divers 518–522
District of Columbia, delegates 8
Fish and Game Protective Association, delegates. 11
Divers, disease 518–522
Diving for sponges 442, 451, 484–485, 489–491, 498–502, 513–542
See also Sponge fisheries.
Dogfish, extermination or utilization urged 67
Dogfish and sea mussels as food 241–257
discussion . 249–257
Donahue, James, lobster question 214–216
Downing, S. W., whitefish production of Great Lakes 627–633
Dragnet in sponge fisheries 517–518
Dredging for sponges 486–489, 517–518
effects on fishery 502–503

'Ear" sponges 424
Ecuador, delegate 6
delegate, address 52–54
fisheries 52–54
Educational exhibit of fishes, plans 1309–1351
See also Exhibits, fishes.
Elephant ear sponges 423
Eggs of fishes, methods of counting . . . 739–741, 1009–1014
transportation cases 741–751, 1039
Egypt, sponge fisheries 480
Elections of the congress 14
Embryology of toadfish 1095–1101
Erie, Lake, fisheries legislation 86
European trouts in America 1405
Evans, A. Kelly, anglers' rights 62
international control of Great Lakes 87
whitefish regulations 687

Page.
Evermann, B. W., international control of boundary waters 85
whitefish regulations 687
Exhibits, educational:
angler's equipment . 1311–1314
fishes . . 1309–1351
arrangement and labeling 1319–1330, 1347–1348
copper-plating fish casts 1362–1363
game species 1311–1314
list of specimens 1330–1340, 1348–1351
material to be used 1317–1319, 1347–1348
plaster casts 1355, 1362
preparation of specimens 1353–1363
subjects to be illustrated 1340, 1343–1347
wax casts from glue molds 1360–1362
Exploration of Mediterranean Sea, international . . 54–56, 67

Fauna of Woods Hole region, study 1225–1263
Feeding of oysters, rate 1306–1308
Feeding salmonoid fry 795–798, 839–851, 1022–1023
Fertilization of salmon eggs 689
whitefish eggs 630–636, 685, 693–694
Field, George W., lobster problem in Massachusetts 209–212
lobster question 217
utilization of dogfish 253–254
Field, Irving A., sea mussels and dogfish as food 241–248, 256
Field Museum of Natural History, delegate 11
Figgins, J. D., preparation of fish specimens . . . 1357–1363
Filters in fish culture 915–916
Fish acclimatization *See* Acclimatization.
Fish and rye meal, fish food 850–851
Fish commissions, state, eggs received from United States . 1394
Fish culture 947–1040
appliances:
aeration 716–717, 1033–1034
attendant's outfit 996
barricades in streams 726–732
bass nests, artificial . 720–721, 993
cleaning devices 1030–1033
cod culture, Norway 799–810
collecting seine 997
collecting tub 995
counting eggs 739–741, 1009–1014
counting fry 739–741, 1001–1004
egg measure 1009–1014
fish retainer 996
food scraper 1034–1035
fry retainer and trap 944
hatching box . . 1015–1024
Norway, hatchery at Flödevig 799–810
oxygenation 716–717, 1033–1034
pond, artificial, and outlet 1027–1028
shipping cases for eggs . 742–751, 998
sorting screen 717–718
turbot culture 866–867
collecting young pond fish 722–723, 997
devices. *See* Fish culture, appliances.
distribution of hatchery products . . 752–757, 1380–1382
feeding salmonoid fry 1022–1023
food for young pond fish 720
salmonoids 795–798, 839–851, 1022–1023
See also Fish food.

Page.
Fish culture—Continued.
  fresh-water shrimp as fish food 853–858
  methods 697–809, 859–870
    agitation of water, continuous 228–234, 767–779, 866–867
    Atlantic salmon 718–719
    brook trout 712–718
    cod 736–737
      Norway 799–816
    flatfish 737
    lake trout 710–712
    marine, Norway 799–816
      United States 736–737, 759–780
      utility 811–816, 1401
    Pacific salmon 725–736
    pike perch 708–710
    pollock 736–737
    pond fishes 719–723
    rainbow trout 712–718, 781–787
    salmon, Atlantic 718–719
      Pacific 725–736
    salmonoids 781–787, 1015–1024
    shad 702–703, 789–794
    striped bass 706–707
    trout 712–718
      rearing methods 714–716, 781–787
      special devices 716–718
    turbot 859–870
    whitefish 707–708
    white perch 704–705
    yellow perch 705–706
  mosquito problem aided 831–838
  new principle 228–234, 759–780, 859–870
  ponds and pond construction 719–720, 1027–1028
    food for adult fish 720
  rescue from overflows 724
  Rhine salmon 824–826
  schools advocated 67
  suitability of water supply 891–906, 1291–1292
  transportation of eggs 741–751, 998
    live fishes 752–757, 780, 1005–1008, 1039
  water conditions 871–928
    gas content 891–906, 1291–1292
    natural impurities 893–894
    poisonous substances 895–898
    treatment to remove algæ 871–890
Fish diseases 907–946, 1409
  brook trout 941–946
  Costia necatrix, prevention 917–928
  fungus, treatment 909–916, 929–932
  gills of young fish 909–912
  salmonoid fry 907–928
  "staggers" 914–916
Fish eggs, measuring and counting 1009–1014
  transportation 741–751, 998
Fish food 839–858, 1022–1023
  device for preparing 1034–1035
  fish and rye meal 850–851
  fly larvæ 842–846
  fresh-water shrimp 853–858
  pond fishes 720
  salmonoids 795–798, 839–851, 1022–1023
  Spratt's prepared foods 846–850
Fish Hawk, United States Fisheries steamer 66, 1375, 1385
Fish, packing for shipment 295–301

Page.
Fish parasites 1151–1210
Fish ponds, artificial 719–720
  with siphoid outlet 1027–1028
Fish products, Peru 347–354
Fish protection:
  black bass 185
  demersal species 145–148
  difficulties 187–192
  fishways 1041–1058
  high seas 142–150
  migratory species 143–145, 184
  salmon, Pacific 184–185
  sturgeon 185
  whitefish 85–87, 89–90, 184, 627–695
Fish, wrapping for shipment 295–301
Fisheries Bureau, United States *See* United States Bureau of Fisheries
Fisheries Commission, International 85–87, 181–186
Fisheries Company, The, award offered by 69
Fisheries:
  beam-trawl 88–89
  China 367–373
  Ecuador 52–54
  fur-seal 315–322
  Galapagos Islands, resources 52–54
  Great Lakes, international control 85–87
  Italy, economic conditions 323–332
  Japan 375–379
  mackerel, effects 281–294
  menhaden, effects 269–294
  Peru 333–356
  preservation on high seas 142
  publications, United States Government 1395–1398
  schooner Grampus 1411
  shad, depletion 1398–1399
  sponge 401–544
    See also Sponge fisheries.
  statistics 1386–1391
  steamer Albatross 1384
    Fish Hawk 1385
  United States 1385–1393, 1410–1411
  whitefish 87, 89–90, 627–695
Fishermen, sponge, appeal for 542–543
Fishery Congress, International 1–76
  See also Congress, International Fishery.
Fishery convention, Anglo-Belgian 167
  Anglo-Denmark 121, 169
  Anglo-French 97, 113, 151, 158
  fur-seal 96, 124, 173, 134
  Great Britain-United States 67, 86
  North Sea 98, 116, 163
  submarine cable 122, 168
  Sweden-Denmark 133, 174
Fishery dictionary 41, 47–49, 64
Fishery dispute, Moray Firth 81, 137, 179–180
  northeast coast, settlement 67
Fishery laws 60–62, 67, 77–198
  See also Fishery regulations *and* Fishery convention.
Fishery regulations, Anglo-Belgian 167
  Anglo-Denmark 121, 169
  Anglo-French 97, 113, 151, 158
  fur-seal 96, 124, 134, 173
  Great Lakes 85–87, 89–90, 181–186, 627–695
  high-seas 77–180

Page.
Fishery regulations, international........ 77-186, 627-695
investigations to precede.................. 83-84, 86
lobsters.................................. 209-217
national.............................. 186, 193-198
North Sea............................. 98, 116, 163
private waters............................ 61-62
shad.............................. 1400, 1401, 1407
simplification urged........................ 67
sponge diving.............................. 522-540
sponge fisheries................... 503-510, 522-540
submarine cable........................... 122, 168
Sweden-Denmark........................... 133, 174
United States and Canada.......... 67, 85-87, 181-186
whitefish..................... 85-87, 89-90, 627-695
Fishery schools, establishment advocated......... 67
Fishery treaty, United States and Canada......... 67, 86
Fishes, acclimatization. *See* Acclimatization.
anatomy.................................. 1211-1224
carriers of mussel larvæ..................... 622-626
changes of density of water, effects......... 1143-1150
copper solution, effects..................... 871-890
counting young............................ 1001-1004
cultivated by United States, list............ 1372-1373
degeneration of American trouts in Austria.... 983-990
destroyers of mosquitoes..................... 831-848
diseases............................ 907-946, 1409
See also Fish diseases.
dissolved content of water, effects............ 891-906
distributions to public in United States..... 1379-1382
exhibit, plans............................ 1309-1351
See also Exhibits, fishes.
foods for........................ 795-798, 839-858
See also Fish culture, foods.
fungus........................... 909-916, 933-940
game, California and Florida................. 201-207
gas content of water, effects................. 898-905
goldfish, Japan............................ 381-397
gunfire, effects............................ 29-32
habits.................................... 1059-1142
breeding of kelpfish..................... 1140-1142
Semotilus.............................. 1125-1135
methods of study....................... 1111-1142
schedule................................ 1066
toadfish (*Porichthys*).................... 1068-1069
(*Opsanus*)............................ 1071-1110
whitefish............................... 649-660
hearing........................... 29-32, 1211-1224
impurities in water, effects.................. 893-894
mosquito destroyers......................... 831-838
natural history............................ 1059-1142
observation of habits............ 1059-1070, 1111-1142
plea for................................ 1059-1069
schedule for............................. 1066
output of United States hatcheries.......... 1379-1382
parasites................................. 1151-1210
See also Parasites.
photography............................... 1122-1125
plans for educational exhibit.............. 1309-1351
plaster casts, preparation................. 1355, 1362
plea for observation of habits............. 1059-1070
poisonous substances in water, effects........ 874-876, 895-898
protection.................... 143-148, 184, 187-198
See also Fish protection.
relation to mosquito problem................. 831-838
Fishes, resistance to copper sulphate............ 871-890
sense of hearing.......................... 1211-1224
study of habits........................... 1111-1142
See also Fishes, habits.
transportation alive................. 1005-1008, 1039
by Fisheries Bureau..................... 1380-1382
wax casts from glue molds................. 1360-1362
wax molds and copperplating............... 1362-1363
Fishing craft of Peru......................... 341-345
Fishing privileges in private waters............ 60, 61-62
Fishing tackle, museum exhibit.............. 1311-1314
Fishways................................ 1041-1058
Atkins.................................... 1048
Brackett.................................. 1046
Brewer.................................... 1047
Cail...................................... 1049
Cail improved........................... 1052-1057
Caméré.................................... 1051
Foster.................................... 1046
Hockin.................................... 1049
Kirk...................................... 1051
McDonald.................................. 1050
Recken.................................... 1052
Richardson................................ 1048
Roberts................................... 1045
Rogers.................................... 1046
Shaw...................................... 1047
Smith..................................... 1045
Steck..................................... 1046
Swazey.................................... 1047
Wheeler................................... 1045
Flatfish culture.............................. 737
Flégel, Ch., appeal to Congress............... 542-543
awarded special prize........................ 72
scaphander in sponge fisheries............... 513-542
Flödevig hatchery, Norway.................... 799-810
Flora of sea bottom, Woods Hole region....... 1225-1263
Florida, delegates............................. 8
game fish and fishing....................... 205-207
sponge fisheries........................... 425-469
regulation.............................. 503-510
statistics.............................. 456-469
See also Sponge fisheries.
grounds................................. 426-431
Fly larvæ, food for fishes.................... 842-846
Food and feeding of oysters................. 1295-1308
Food of oysters, volumetric determination..... 1304-1308
supply, determination.................... 1297-1304
Food for fishes................ 795-798, 839-858, 1022-1023
See also Fish food.
Foreign governments, delegates................. 6-7
Foreign societies, delegates.................... 6-7
"Forest and Stream," award offered.............. 69
Forest reserves, establishment favored........... 67
France, sponge fisheries........................ 477
Franke, Johann, Costia necatrix in salmonoid fry. 917-928
degeneration of American trouts in Austria.... 983-990
Franklin, Dwight, award received................ 71
preparation of fish specimens............. 1353-1356
Fresh-water mussels, culture................... 1409
life history............................... 618-622
Fresh-water shrimp, a natural fish food........ 853-858
Fryer, Charles E., international fisheries regulations....................................... 91-102
beam trawling, effects on fish supply.......... 89

Page.
Fryer, Charles E., exploration of Mediterranean Sea . 55
international fishery regulations 83, 179
lobster question 216
Moray Firth dispute 179
sea mussels and dogfish as food 250, 251
whitefish regulations 688-689, 695
Fry retainer and trap 994
Fuller, Alfred E., fish-cultural devices 991-1000
Fullerton, S. F., whitefish regulations 694, 695
Functions of ear of squeteague 1211-1224
Fungus, fishes in captivity 909-916, 929-940
young salmonoids in hatchery 909-912
Fur seals and seal fisheries 315-322
Fur-seal regulations 96, 124, 173, 134, 321

Galapagos Islands, fishery resources 52-54
Game fishes, California and Florida 201-207
museum exhibit 1311-1314
protection 187-192, 193-198
Game fishing 187-208
legislation 187-198
privileges in private waters 61-62
Gas content of water, correction in fish culture ... 898-905
fishes affected 898-905
Wisconsin lakes 1273-1294
Georgia, delegates 8
German carp in United States 1405-1406
German Fisheries Society, delegates 7
German Society of Anglers, delegate 7
Gill, Theodore, award offered by 70
called to chair 63
observation of habits of fishes as against undue generalization 1059-1070
dogfish and sea mussels as food 249, 251, 256, 257
Semotilus 65
toadfishes 1069
Gills, disease of, in young fish 909-912
Gloucester, Mass., visit to 66
Board of Trade, courtesies extended 66
delegate 10
Glove sponges 419
Glue molds for casts of fishes 1360-1362
Godoy, José F., address 51-52
named as vice-president 25
Goldfish, culture in Japan 386-397
Japanese varieties 383-386
Grafting sponges 553-555
Grampus, United States fisheries schooner 1411
Grass sponges 416
Great Britain and United States fishery convention . 67
fisheries commission 181-186
Great Lakes, international control 85-87
whitefish fishery conditions 87, 637-639, 676-682
whitefish production 627-695
Greece, sponge fisheries 522-530
Greenland seal-fishery regulations 134
Guano industry and fisheries of Peru 333-365
Guano producing birds of Peru 358-362
Guatemala, delegate 6
Gudger, E. W., habits and life history of toadfish 1071-1110
Gunfire, effects on fishes 29, 30, 32

Habits of fishes 1068-1142
See also Fishes, habits

Page.
Hardhead sponges 420
Harpooning sponges 485-486, 497-498
Hatch, Edward, jr., water pollution 42
Hatchery, diseases of fish 909-928
Hatching of fishes 697-780, 859-870
See also Fish culture.
Hathaway, Walter E., menhaden fishing, effects ... 269-277
gun practice, effects on fishes 30
utilization of dogfish 254
Hearing in fishes 29-32, 1211-1224
Heterostichus rostrata, spawning habits 1140-1141
High seas, definition 105
international fishery regulations 77-180
jurisdiction 109-112
Hinrichs, Henry, international control of Great Lakes 90
Hoek, P. P. C., address 23
beam trawling, effects 89
named as vice-president 24
propagation and protection of Rhine salmon ... 817-830
Holder, C. F., combating fungus 933-936
exhibit of fishes and anglers' equipment 1309-1314
sport fishing in California and Florida 201-207
studying life history of fishes 1137-1142
transporting live fishes 1005-1008
Holt & Co., Henry, award offered by 70
Honduras sponge fisheries 474
Honeycomb sponges 423
Hooking sponges 435-442, 497-498, 517
Horned dace, breeding habits 1125-1136
Hydrogen dioxide, remedy for fungus 929-932
Hydrophysics, Wisconsin lakes 1273-1294

Idaho, delegates 8
Illinois, delegates 8
Impurities of water, effects upon fishes 893-894
Indian Ocean sponges 493
Indiana, delegates 8
International committee on awards 68, 71
International explorations of Mediterranean 54-56, 67
International fisheries commission, United States and Canada 85-87, 181-186
International Fishery Congress 1-76
See also Congress, International Fishery.
International Fishery Congresses, Permanent Commission 35, 41, 73
International fishery dictionary 41, 47, 49, 64
International fishery regulations 77-186
See also Fishery regulations and Fishery convention
International Office of Documentation for Fisheries, delegate 6
International waters of United States and Canada .. 67
Investigations, biological, United States 1383-1385, 1406-1410
laboratories of United States Government 1384
Mediterranean, international 54-56, 67
oyster fattening 1407
pearl mussel 615-626, 1409
precede legislation 83-84, 86
Iowa, delegates 8
Italian Fisheries Society, delegate 7
invitation to congress to meet in Rome 41
thanks offered to 67
Italy, American fishes acclimatized 947-954
delegates 6
economic conditions of fisheries 323-332

	Page.
Jamaica sponge fisheries	475
Japan, American fishes	39
delegate	6
fisheries	375–379
goldfish and their culture	381–397
Johnson, F. M., award offered by	70
Jordan, David Starr, message	46
International Fisheries Commission	181–186
Kadich, Heinrich von, named as vice-president	24
Kelpfish, spawning habits	1140–1142
Kendall, W. C., effects of menhaden and mackerel fisheries	279–294
Kincaid, Walter S., transporting fish eggs and fish	1039
Kitahara, Tasaku, named as vice-president	25
American fishes in Japan	39
fisheries of Japan	375–379
Laboratories, biological, United States Government	1384
Lacustrine physics	1273–1294
Lake Erie, fisheries legislation	86
Lake Ontario, fisheries legislation	87
Lake trout culture	710–712
Lakes of Wisconsin, gaseous changes	1275–1294
Lampedusa, sponge fisheries	483–484
Larvæ of flies, fish food	842–846
League of American Sportsmen, delegate	11
Lefevre, George, culture of fresh-water mussels	615–626
Legislation, fishery	67, 77–198, 209–217, 503–508, 522–540, 627–695
See also Fishery regulations and Fishery convention.	
Libby, T. E., dogfish as food	251
Library of Congress, visit	37
Life history of fishes	1059–1141
methods of study	1111–1142
toadfish	1071–1110
Linton, Edwin, flesh parasites of marine food fishes	1195–1210
Lobster, acclimatization on Pacific coast	1406
culture, methods	219–240, 737–739
results	213, 1401
Rhode Island	213, 219–240
discussion of problem	213–217
habits of young	221–227
laws of Maine	214–216
Massachusetts	209–212
Rhode Island	213
problem in Massachusetts	209–212
protection	208–217
Louisiana, oyster culture	1408
Lucas, Frederic A., award received	71
educational exhibit of fishes	1341–1352
Luncheon by Alaska Packers Association	60
American Fisheries Society	36
Blue Ridge Rod and Gun Club	41
Lydell, Dwight, whitefish regulations	694
Machine diving in sponge fisheries	489–491, 498–502, 513–542
abuse	513–542
diseases of divers	518–522
effects on fisheries	498–502
regulations	503–504, 522–540
Mackerel, fisheries	279–293
habitat and movements	283–288

	Page.
Maine, angling	62
delegates	8
lobster culture	214
lobster protection	214–216
Mammals, aquatic, protection	148–150
Marine fish culture:	
methods	736–738, 799–810
Norway	799–816
United States	736–739, 1401
new principle	759–780, 859–870
turbot	859–870
utility	811–816, 1401
Marine fishes, flesh parasites	1195–1210
Marsh, M. C., destruction of algæ in fish-cultural waters	871–890
dissolved content of water in its effect upon fishes	874–876, 891–906
Maryland, delegates	8
Maryland Fish and Game Protective Association, delegate	11
Massachusetts, delegate	8
lobster question	209–212
Master Mariners' Association, courtesies extended	66
Matsubara, S., goldfish in Japan	381–397
Mead, A. D., awards received	71
aquiculture, new principle	759–780
lobster culture, method	219–240
Meal, rye, as fish food	850–851
Measuring fish eggs	739–741, 1009–1014
Meehan, W. E., whitefish regulations	690
Mediterranean, international explorations	54–56, 67
sponge fisheries	476–481
methods	484–491
regulation	522–538
Members of the congress	5–13, 14, 15
Menhaden, habitat and movements	283–287
fisheries, effects	269–294
spawning	288–290
Merrill aerating cone	717
Methods, fish culture	697–809, 859–870
fish disease, prevention	907–946
lobster culture	219–240, 737–739
mussel culture	615–626, 1409
packing fish for shipment	295–301
photography, subaquatic	1122–1125
sponge culture	545–614
study of fishes	1111–1142
volumetric determination of oyster food	1295–1308
See also Fish culture; Lobster culture; Sponge culture; Oyster food.	
Mexico, delegate	6
address	51–52
sponge fisheries	475
Michigan, delegates	8
Mid-Atlantic Ocean, sponges	493–494
Miner, Roy W., award received	71
educational exhibit of fishes	1315–1340
Minnesota, delegates	8
Minutes of the congress	15
Mississippi, delegates	8
Missouri, delegates	8
Montana, delegates	9
Moore, Henry F., awards received	71
food and feeding of oysters	1295–1308
sponge culture	545–585
sponges and sponge fisheries	401–511

Page.
Moray Firth, fisheries dispute 81, 137, 179
Morocco, sponge fisheries 484
Mosquito problem, relation of fishes 831–838
Mowbray, L. L., effects of gunfire on fishes 32
Museum of the Brooklyn Institute of Arts and Sciences, award offered by 69
Museum exhibit of fishes, plans for 1309–1351
See also Exhibits.
Mussel culture, fresh-water, experiments 1409
method 615–626
salt-water 245–247
Mussels, fresh-water, life history 618–622
salt-water, as food 241–247

Narragansett Bay, visit 65
National aspects of angling 193–198
National Association of Audubon Societies, delegates 11
National Association of Fish Wardens and Commissioners, delegates 11
National Association of Scientific Angling Clubs, delegates 11
National fisheries control 186
National Museum, United States, delegates 5
Natural history of fishes 1059–1141
horned dace 1125–1135
Rhine salmon 819–824, 830
toadfish 1071–1110
Naumann, Walther, named as vice-president 25
Naval gun practice, effects on fishes 29–32
Navigation laws, international 99
Nebraska, delegates 9
Nebraska University, delegate 11
Nests for pond fishes 720–721, 993
Netherlands, delegate 6
Netherlands Reclamation Society, delegate 7
Nevada, delegates 9
New England Forest, Fish, and Game Association, delegates 11
exhibition of motion pictures 33
New Mexico, delegates 9
New York, delegates 9
Academy of Sciences, award offered by 70
Aquarium, award offered by 69
reception 65
Botanical Garden, award offered by 69
Zoological Society, delegate 11
New Zealand, American fishes acclimatized 967–976
delegate 6
geographical features 974
sponge fisheries 492
Nicaragua sponge fisheries 475
Nordqvist, Oscar Fritiof, named as vice-president 25
dogfish as food 249
gas content of water 1293
North, Paul, lobster question 217
whitefish regulations 686–687, 695
North Carolina, delegates 9
North Sea fishery regulations 98, 116, 163
Norway, marine fish culture 799–816
Nude diving for sponges 484–485, 516–517
effects on fishery 498

Observation of fishes, photography 1122–1125
Officers of the International Fishery Congress 3–4
Ohio, delegates 9
Oklahoma, delegates 9

Page.
Olsen, O. T., named as vice-president 25
international fishery regulations 79–82, 179
international fishery dictionary 49
Moray Firth dispute 81, 179
Ontario Forest, Fish, and Game Protective Association, delegate 7
Ontario Lake, fisheries legislation 87
Opsanus tau, habits and life history 1071–1110
Oral incubation among fishes 1069
Oregon, delegate 9
Organization of the congress 3–16
Osborn, H. F., reception 65
Outlet, artificial fish pond 1027–1028
hatching trough 1029–1030
Oxygen changes, Wisconsin lakes 1287–1292
Oxygenation device for fish culture 716–717, 1033–1034
Oysters:
culture, advance in southern states 1408
food supply, determination 1297–1304
water-specimen cup 1299–1301
fattening experiments 1407
fisheries of English Channel, regulation 97
food and feeding, methods of studying 1295–1308
rate of feeding 1306–1308
grounds, suitability for planting 1297–1304
wholesomeness 259–267
pearl oysters and X-ray process 303–313
Ozone, a remedy for fungus on fishes 937–940

Pacific Ocean sponges 493
Pacific salmons:
acclimatization 955–976
culture 725–736
results 1400–1401
See also Salmon.
Packing fish for transportation 295–301
Paige, Charles L., foods for young salmonoids 795–798
rainbow trout culture 781–787
Parasites of fishes 1151–1210
Atlantic salmon 1153–1173
butterfish 1202–1206
marine fishes 1195–1210
new cestodes 1185–1188
new trematode 1176–1184
Pacific salmon 1172–1173
Sebago salmon 1151–1194
Parcage of sponges 598–599
Paris fur-seal tribunal 124, 173
Parker, G. H., structure and functions of ear of squeteague 1211–1224
Pearl fisheries and X-ray process 303–313
Pearl mussels, fresh-water, culture methods 615–626, 1409
Pelagic sealing 42, 125–132, 321
Pennsylvania, angling 61
delegates 9
Fish Protective Association, delegates 11
Perce, H. Wheeler, national aspects of angling 193–198
Permanent Commission of International Fishery Congresses 35, 41, 73
Peru, delegate 6
fish products 347–354
fisheries and guano industry 333–365
fishing boats 341–345
geographic features 335–338
guano-producing birds 358–362
methods of preserving fish products 347–354

Page.
Pew, John J., anglers' rights 61
beam trawling 88
dogfish as food 252
Philadelphia Aquarium Society, delegates 11
Philippine Islands, sponge fisheries 491–492
Photography of live fishes 1122–1125
Physics of lake waters, Wisconsin 1273–1294
Pisciculture 627–1040
See also Fish culture.
Pinchot, Gifford address on conservation 57–59
Pirko, Franz von, American fishes in Austria 977–982
Plaster casts of fishes, preparation 1355, 1362
Poisonous substances in water, effects upon fishes. 895–898
Pollock culture 737
Pollution of water 42, 896–898
Pond, artificial, with siphoid outlet 1027–1028
Pond culture 719–723
artificial nests 720–721, 993
brood fish 721–722
collecting young fish 722–723
seine 997
tub 995
fish retainer 996
food for adult fish 720
fry retainer and trap 994
pond construction 719–720, 1027–1028
Prince, Edward E., named as vice-president 24
acclimatization of fishes in New Zealand 974
fish culturist, training 44
habits of fishes 1068
sea-mussels and dogfish as food 252–253
whitefish beds, pollution 694
whitefish production 685
propagation 685
Proceedings of congress, editing and publication 67
Programme committee 27
Prepared foods for fishes 846–851
Preservation of fish for shipment 295–301
Preservation of fisheries. *See* Protection.
President of the United States, reception 36
remarks 36
stand for conservation commended 67
Propagation of fishes 627–1040
fresh-water mussels 615–626, 1409
lobsters 213, 219–240, 737–739
oysters, southern states 1408
Rhine salmon 824–826
sponges 545–614
See also Fish culture; Oysters; Sponge culture.
Protection of aquatic mammals 148–150
fishes 184–185, 186, 187–192
lobsters 209–217
pearl oysters 303–313
sponge fisheries 503–510
See also Fish protection.
Proteocephalus pusillus, a new cestode parasite 1186–1188
Publications of International Fishery Congress 15
United States Bureau of Fisheries 1395–1398
Published works presented to the congress, list 74

Racks in salmon streams, designs 726–732
Rainbow trout:
acclimatized in Argentina 955–966
Austria 977–982
eastern states 1404
Italy 947–953
New Zealand 967–976

Page.
Rainbow trout—Continued.
culture, methods 714–718, 781–787
diseases 907–928
food for 795–798
"staggers" in fry 914–916
Rathbun, Richard, named as vice-president 25
Reef sponges 419
Regulation of fisheries 67, 77–198, 627–695
See also Fishery regulations.
Regulations of the International Fishery Congress 14–15
Reighard, Jacob, award received 72
methods of studying life history of fishes 1111–1136
Reighard, Paul, award received 71
whitefish production of Great Lakes 643–684
Resolutions adopted by the congress 67–68
committee 26, 63
method of adoption 14
Resources of the congress 15
Rhine salmon, propagation and protection 817–830
Rhode Island, delegates 9
Fish Commission, reception 66
lobster question 213
Rights to members 14
Robinson, R. K., destruction of algæ in fish-cultural waters 871–890
counting young fishes 1001–1004
aerating apparatus 717
Rome, invitation to congress to meet 41
Root, Henry T., effects of gunfire on fishes 32
lobster question 213
Rosenberg, Albert, abating disease of trout 941–946
Rossati, Guido, fisheries of Italy 323–332
Roumania, delegates 6
Rowe, Henry C., courtesies extended 65
wholesomeness of oysters 259–267
Royal Geographical Society, delegate 7
Russia, nonparticipation in congress 38
Rye meal and fish as fish food 850–851

Salmon, Alaska inspection service 1392–1393
Salmon, Atlantic, culture 718–719, 1399–1400
feeding fry 1022–1023
hatching box 1015–1024
parasites 1153–1173
Salmon, Pacific:
acclimatized in Argentina 955–966
New Zealand 967–976
culture 725–736, 1400–1401
barricades 726–732
fertilization of eggs 689
fisheries of Columbia River 186
parasites 1172–1173
protection 184–185
spawntaking and hatching methods 732–736
Salmon of Rhine 817–830
natural history 819–824, 830
propagation and protection 824–827
Salmon, Sebago, culture 718–719
parasites 1151–1194
Salt-water mussels as food 241–247, 249–257
Salt-water treatment for fungussed fishes 929–932
Santa Catalina Island, sport fishing 201–205
Santo Domingo sponge fisheries 475
Scaphander in sponge fisheries 489–491, 498–502, 513–542
Schools of fisheries and fish culture advocated 67
Schooner Grampus, United States Fisheries 1411

Page.
Scientific fishery investigations, United States . . 1383–1385, 1406–1410
Scott, G. G., effects of changes in density of water upon blood of fishes . . . 1143–1150
Sea bottom, fauna and flora . . . 1225–1263
Sea-fish hatching, utility . . . 811–816
Sea fisheries, international regulations . . . 77–180
Sea mussels and dogfish as food . . . 241–257
Seal, William P., relation of fishes to mosquito problem . . . 831–838
Seal fisheries . . . 315–322
Antarctic . . . 317–319
pelagic . . . 42, 125–132, 321
regulations . . . 96, 124, 134, 173
Seals, Antarctic . . . 317–319
northern . . . 319–322
Sebago salmon, internal parasites . . . 1151–1194
Secretary-General, resolution concerning . . . 67
Sellers, M. G., anglers' rights . . . 60
Semotilus, natural history . . . 1125–1135
breeding habits . . . 1125–1136
nest building . . . 65
Sessional business . . . 17–76
Shad, acclimatized on Pacific coast . . . 1402–1403
culture, method . . . 702–703
expansion of work . . . 789–794
results . . . 1398–1399
fishery, depletion . . . 1398–1399
need of legislation . . . 67, 1407
Sheepswool sponges . . . 411
Shipment of fish, method of packing . . . 295–301
Shipping cases for fish eggs . . . 742–751
Shrimp, fresh-water, as fish food . . . 853–858
Sicilian Sea, sponge fisheries . . . 483–484
Simms, G. E., hatching boxes and feeding of fry . 1015–1024
Siphoid outlets for ponds and troughs . . . 1027–1030
Smith, Hugh M., address . . . 21
named as secretary-general . . . 23
oral incubation among fishes . . . 1069
menhaden . . . 277
Smith, H. Stephenson, New Zealand, topography . . . 974
Smithsonian Institution, award offered by . . . 69
delegates . . . 5
Snyder sorting screen . . . 717–718
Society for Promotion of Norwegian Fisheries, delegate . . . 7
Sölling, A., packing fish for shipment . . . 295–302
Solomon, John I., award received . . . 72
process for preserving pearl oyster fisheries . . . 303–313
South Carolina, delegates . . . 9
South Dakota, delegates . . . 9
Spain, sponge fisheries . . . 477
Sparganum sebago, new cestode parasite . . . 1185
Spencer, L. B., combating fungus . . . 929–932
Spawning habits of horned dace . . . 1125–1136
Spawntaking, Pacific salmons . . . 732–736
trout in Colorado . . . 713–714
See also Fish culture.
Sponge culture . . . 545–614
collectors for larvæ . . . 599–604
critical review . . . 587–613
cuttings . . . 555–585, 604–613
essential considerations . . . 581–583
experiments by Bureau of Fisheries . . . 1408
experiments reviewed . . . 590–613

Page.
Sponge culture, financial aspects . . . 583–585, 609–610
grafting . . . 553–555
growing from dissociated tissues . . . 555, 1265–1272
growing from eggs . . . 554
not feasible . . . 587–613
parcage . . . 598–599
planting . . . 594–598
practical method . . . 545–585
Sponge divers, appeal for . . . 542–543
disease of . . . 518–522
Sponge diving . . . 442–451, 513–543
Sponge fisheries:
Adriatic Sea . . . 477–478
Ægean Sea and Asia Minor . . . 478–479
Algeria . . . 484
Australia . . . 492
Bahama Islands . . . 470–472
conditions and effects . . . 494–503
Cuba . . . 472–474
depletion of beds . . . 494–497
diving, machine . . . 442–451, 489–491, 513–542
nude . . . 484–485, 498, 516–517
dredging or trawling . . . 486–489, 502–503, 517–518
effects upon sponge beds . . . 494–503
Egypt . . . 480
Florida . . . 425–469
methods . . . 435–456
regulation . . . 503–510
statistics . . . 456–469
Greece, regulation . . . 522–530
harpooning . . . 485–486, 497–498
hooking . . . 435–442, 497–498, 517
killing and curing the catch . . . 451–453
Lampedusa . . . 483–484
legislation . . . 503–510, 522–540
Mediterranean . . . 476–491, 522–538
methods, Florida . . . 435–456
Mediterranean . . . 484–491, 516–518
mid-Atlantic Ocean . . . 493–494
Morocco . . . 484
needs . . . 547–550
New Zealand . . . 492
Philippine Islands . . . 491–492
regulation and protection . . . 503–510, 522–542
statistics, Florida . . . 456–469
scaphander, abuse . . . 489–491, 513–542
Sicilian Sea . . . 483–484
Spain and France . . . 477
trawling or dredging . . . 486–489, 502–503, 517–518
Tripoli . . . 481–482
Tunis . . . 482–483
United States . . . 425–469, 538–540
wading . . . 484
western Atlantic . . . 470–475
Sponge trade, United States . . . 453–456, 469–470
methods of buying . . . 453
United States and foreign countries . . . 469–470
Sponges . . . 401–511, 587–614
bleaching . . . 456
common names in different languages . . . 410
development from tissue cells . . . 555, 1265–1272
elephant-ear . . . 424
fisheries . . . 401–511
See also Sponge fisheries.
glove . . . 419

Page.
Sponges, grass 416
hardhead 420
honeycomb 423
killing and curing 451–453
live 404
Indian Ocean 493
Mediterranean varieties 422–425
Pacific Ocean localities 493
packing 454
reef 419
requisites 407–410
sheepswool 411
Turkey cup 422
Turkey toilet 422
varieties 410–425
velvet 415
western Atlantic varieties 411–421
wire 421
yellow 413
zimocca 423
Sport fishing 187–208
California and Florida 201–207
legislation 187–198
museum exhibit 1311–1314
national aspects 193–198
private waters 61–62
Spratt's fish foods 846–850
Squeteague, structure and functions of ear 1211–1224
Squires, George P., menhaden fishing 278
"Staggers" in rainbow trout fry 914–916
State fish commissions, eggs received from United States 1394
Statistics, Florida sponge fisheries 456–469
United States fisheries 1386–1391
Steamer Albatross, United States Fisheries 1384
Steamer Fish Hawk, United States Fisheries 1385
Steam-trawl fishing 84–85, 88–89
Steindachner, Franz, message 29
Stevenson, Charles H., award received 71
international fishery regulations 103–178
Stranahan, J. J., fertilization of whitefish eggs 693–694
dissolved content of lake waters 1293
Straus, Oscar S., address 18
Striped bass, acclimatized on Pacific coast 1403–1404
culture 706–707
Structure of ear of squeteague 1211–1224
Study of habits of fishes, methods 1111–1142
plea for observation 1059–1070
Sturgeon, protection 185
Subaquatic photography 1123–1125
Submarine cable convention of 1884 122, 168
Sumner, F. B., fauna and flora of sea bottom 1225–1263
effects of gunfire on fishes 30
Sunfish, acclimatization 947–954
Sweden, delegate 6
Sweden-Denmark fishery convention 133, 174

Tackle, fishing, museum exhibit 1311–1314
Temperatures, Woods Hole region 1238–1239
Tennessee, delegates 10
Territorial waters 79–80, 105–109, 136–142
definition 105–109
jurisdiction, extension of 136–142
Texas, delegates 10
Thompson, W. T., fish-cultural results in Colorado 691–692
trout of Colorado 695

Page
Titcomb, J. W., fish-cultural practices 697–757
acclimatization of fishes in New Zealand 974
whitefish regulations 689–690
Toadfish (*Porichthys*) habits 1068, 1069
(*Opsanus*) habits and life history 1071–1110
Toilet sponges, Turkey 422
Townsend, C. H., fur seals and seal fisheries 315–322
reception 65
Transportation, fish eggs 741–751, 1039
fishes, method 752–757, 780, 1005–1008, 1039
United States Fisheries Bureau 741–751, 1380–1382
Trap for bass fry 994
Trawl fishing 84–85, 88–89
Trawling for sponges 486–489, 517–518
effects 502–503
Treaty, fisheries 67, 113–136, 151–174
See also Fishery convention.
Tripoli, sponge fisheries 481–482
Trout:
acclimatized in Argentina 955–966
Austria 977–990
Colorado 1402
eastern states 1404
Italy 947–953
New Zealand 967–976
culture, aeration apparatus 716–717
brook trout 712–713
lake trout 710–712
methods 714–716, 781–787
rainbow trout 713–716, 781–787
rearing 714–716
sorting screen 717–718
spawntaking in Colorado 713–714
special apparatus 716–718
disease of fry 917–928, 941–946
European, in America 1405
foods 795–798, 839–851
resistance to copper sulphate 871–890
"staggers" in fry 914–916
T-wharf Association, courtesies extended 66
Tulian, E. A., American fishes in Argentina 955–966
Tuna Club, delegate 11
Tunis, sponge fisheries 482–483
Turbot culture 859–870
Turkey cup sponges 422
Turkey toilet sponges 422

United States and Great Britain fisheries commission 85–87, 181–186
United States Bureau of Fisheries 5, 70, 697–757, 1365–1411
acclimatization of fishes 1402–1406
award offered by 70
biological investigations 1383–1385, 1400–1410
extent of work 699–702
fish-cultural work 697–757, 1371–1385, 1398–1402
hatcheries 1373–1379
history and work 1365–1411
investment 1370
laboratories 1384
organization 1369
output of hatcheries 1379–1382
publications 1395–1398
relations abroad 1393–1395
with states 1393–1395
resources 699–702, 1370
species of fishes cultivated 1372–1373

Page.
United States, delegates to Fishery Congress...... 5-6
views of delegates.......................... 67
fisheries...................... 1385-1393, 1410-1411
statistics.......................... 1386-1391
President's stand for conservation commended... 67
sponge fisheries................... 425-469, 538-540
University of Nebraska, delegate................ 11
Uruguay Lobos Fishing Company, message regarding pelagic sealing....................... 42

Velvet sponges............................... 415
Venezuela sponge fisheries..................... 475
Vermont, delegates.......................... 10
Vice-presidents of the congress.................. 24
Views adopted by the congress................ 67
Vincent, Eugene, causes of disease in young salmonoids.......... 907-916
devices for fish culture................... 1027-1036
Vinciguerra, Decio, invitation to congress to meet in Rome............................... 41
Mediterranean Sea, exploration............... 54, 55
named as vice-president...................... 25
next meeting of congress..................... 42
Virginia, delegates.......................... 10
von Bayer, H., fishways.................. 1041-1058
measuring fish eggs.................. 1009-1014
von Kadich, H., named as vice-president.......... 24
von Pirko, Franz, American fishes in Austria.... 977-982

Wading for sponges........................ 484
Ward, Henry B., internal parasites of Sebago salmon.................. 1151-1194
Washington, delegates......................... 10
Washington, D. C., Board of Trade, delegates...... 10
Chamber of Commerce, delegates............... 11
Water, conditions in fish culture............... 871-989
copper sulphate to destroy algæ.............. 871-890
density changes, effect upon fishes.......... 1143-1150
dissolved content, effect upon fishes.......... 891-906
dissolved gases, effects on fishes.............. 898-905
fish cultural, filter.......................... 915-916
gaseous changes..................... 1291-1292
suitability.................... 891-906, 1291-1292
removal of algæ.......................... 871-890
treatment with copper sulphate............ 871-890
gas content, Wisconsin lakes.............. 1273-1294
impurities, effects on fishes.................. 893-894
pollution, effects on fishes................... 896-898
treatment with copper sulphate.............. 871-890
Water-specimen cup, for oyster culture....... 1299-1301

Page.
Wax casts of fishes, preparation........ 1355, 1360-1362
West, Henry L., address........................ 20
West Virginia, delegates....................... 10
Fish and Game Protective Association, delegates.. 11
Western Atlantic sponge fisheries.............. 470-474
Wickford, Rhode Island, visit to................. 66
Wilson, C. H., international control of Great Lakes. 89
whitefish production........................ 686
Wilson, H. V., development of sponges from tissue cells............................... 1265-1272
Wire sponges................................ 421
Wisconsin, delegates........................... 10
lakes, gas content of water............... 1273-1294
Whitefish, acclimatization in New Zealand...... 970, 973
breeding habits......................... 629-630
catch and plants in Great Lakes............. 660-673
culture, effects............................ 673-676
method................................ 707, 708
plan to increase production............... 627-695
discussion......................... 40, 43, 685-695
fertilization.......................... 685, 693-694
fishery, conditions................ 87, 89-90, 637-639
regulation............................ 627-695
habits...................... 184, 629-630, 649-660
legislation.................. 86, 87, 639-641, 676-681
natural history.......................... 649-660
percentage of fertilization....... 630-636, 685, 693-694
production in Great Lakes, plans to promote... 627-695
propagation...................... 627-695, 707-708
protection........................... 184, 627-695
White perch culture......................... 704-705
Whitman, E. C., utilization of dogfish.......... 255, 256
Wholesomeness of oysters as food............. 259-267
Wolverine Fish Company, award offered by....... 70
Woods Hole, Massachusetts, visit to............ 66
Woods Hole region, density of water............. 1240
fauna and flora studied.................. 1225-1263
temperature of water.................... 1238-1239
Worms as fish food....................... 1022-1023
Worth, S. G., expansion of shad-hatchery work.. 789-794
fresh-water shrimp as fish food............. 853-858
washing of lands........................... 59
Wyoming, delegates........................... 10

X-ray process in pearl fisheries................ 303-313

Yellow perch culture........................ 705-706
Yellow sponges............................... 413
Yen, Wei-ching W., named as vice-president...... 25
fisheries of China.......................... 367-373

O